AN AGRICULTURAL HOUSEHOLD MODEL FOR BURKINA FASO, WEST AFRICA

By

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To Nana Ama and Kwasi

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Agricultural households are often household-firms which behave as both producers and consumers of goods. Household-firms may have unexpected economic responses to price changes. When the price of the good both produced and consumed increases, profits will increase for the firm. Increased profits increase household income and consumption of the good. However, a household facing higher prices will normally decrease consumption of that good. The result of these opposing economic forces is explored in this study.

A literature review of agricultural household models and results from other empirical studies are presented. The theory of the household-firm and its indefinite conclusion on price responsiveness supports the need for empirical

testing. The model requires econometric estimation of both the production and consumption sides of household behavior.

Household level data collected in Burkina Faso during 1984 are used to model production under a Cobb-Douglas specification with land and labor inputs. Results are satisfactory with labor a binding constraint on the production process. Lack of household level agro-climatological information explains the remaining variability in the data.

Household consumption is modeled under an Almost Ideal Demand System (AIDS) with prices and total expenditures as arguments. A linear approximation (LA/AIDS) using the Stone price index is estimated with Full Information Maximum Likelihood (FIML). Encouraging results with significant and correctly signed expenditure and price effects are obtained.

Demand and supply elasticities are derived for the household. Output price elasticity of demand is computed with and without the profit effect resulting in a reduced response, but no sign change. Results are attributed to two factors; first, data were collected during a poor agricultural year and most households were net purchasers of cereals, thereby reducing the profit effect. Secondly, household income diversification strategies in response to highly variable agroclimatic conditions in the Sahel have resulted in less dependence on agricultural output as a source of household income, again resulting in a reduced profit effect.

CHAPTER I
INTRODUCTION

The majority of empirical studies in agricultural economics are microeconomic in nature. In fact, some would argue that agricultural economics is best characterized as empirical microeconomics. Neoclassical microeconomic theory concerns the firm in production and the household in consumption. In developing countries the majority of agricultural households act as both a firm and a household. They provide their own labor and consume the bulk of their own production. Thus, decisions concerning production, consumption and labor in developing countries often influence each other within household-based economies. That the household is the chosen unit of analysis should come as no surprise to most economists. The foundation of consumption economics is the household. Recall also that the word "economics" originates from ancient Greek and means the "laws that govern the household."

This study outlines an integrated theoretical and empirical approach to deal with agricultural households which are both producers and consumers of goods that originate from the household-firm. A theoretical framework is proposed for a model that integrates both the production and

consumption aspects of household behavior in developing countries. The resultant agricultural household model is tested on cross-sectional household data from Burkina Faso, West Africa. Drawing on a wealth of production, demographic and expenditure data from the early 1980s in four villages within Burkina, an integrated, consistent, conceptual model is estimated to provide insights into the behavior of agricultural household-firms.

Because these household-firms consume part of their own production they may behave differently in response to price changes. Specifically, an increase in the price of the output they produce may increase their net profits, thereby inducing an increase in income that would counterbalance or outweigh the traditional negative impact on their consumption of that output due to the increase in its price.

Problem Statement

Basic information about household behavior is essential for the formulation of appropriate policy in the agricultural sector of any country, whether the goal of that policy is household welfare or increased production. Price and income elasticities are needed in order to capture and describe the behavioral responses of household producers and consumers to policy shifts. In particular, tax and subsidy policies will be dependent on an accurate determination of supply and demand responses of households. Microlevel

information is important in order to guide economic policies that will correctly anticipate individual behavior under a particular policy environment. In other words, will the people under the policy behave as the policy anticipates, or in a different manner?

The advent of structural adjustment policies throughout Africa in the 1980s has made it increasingly important to understand the impact of price changes. Structural adjustment programs, supported by multilateral donor agencies such as the World Bank and the International Monetary Fund, generally insist on increased prices for agriculturally produced goods as an incentive to farmers. However, in economies where producers are also consumers the impact of changes in output prices may not have the desired affect on household consumption or production.

Furthermore, due to the plethora of social and economic structures in developing countries, there is a lack of basic descriptive and quantitative information on agricultural households in different regions. This kind of information is especially lacking in African countries which only gained independence within the last twenty to thirty years and set out to transform their agricultural sectors. As we will find in the literature review, the majority of the agricultural household models that have been performed to date have been for Southeast Asian countries.

Objectives of the Study

The principal goal of this study is to determine household response to economic incentives through the determination of elasticities from an agricultural household model that integrates both consumption and production aspects of the household-firm. The specific objectives are to:

1. provide descriptive and quantitative information concerning the production and consumption behavior of rural African households,
2. combine both production and consumption aspects of agricultural households in an integrated econometric model,
3. estimate income and price elasticities of demand using pooled data,
4. estimate output supply and input demand equations using cross-sectional data, and
5. introduce and empirically measure the impact of the "profit effect" on cereal consumption.

Agricultural Household Models

The general class of agricultural household models was chosen as the framework for analysis. These models are especially suited for modeling the behavior of agricultural households in developing economies because of their ability to integrate both consumption and production aspects of the household.

Consisting of a variant of consumer choice theory in which the production technology is represented in the income

constraint by a profit function, agricultural household models are within the neoclassical paradigm. However, they do allow an additional flexibility in modeling with regard to the consumption response of households to exogenous changes via the income term, often called the "profit effect."

It is through the income term that the two sides, production and consumption, are linked. For an agricultural household that obtains the preponderance of its income from the sale of agricultural commodities, it is the production technology that first dictates income, which is usually modeled via a profit function. However, once this income level is established, it becomes an argument in the determination of the level of indirect utility. The result is a recursive model where production decisions precede and delimit consumption decisions, but not vice versa. The recursive nature of these models is dependent upon the existence of competitive input and output markets.

Recursive decisions are thought to be sequential in that one set of decisions precedes and subsequently sets parameter values for other decisions. Recursive decisions are often described as separable because a set of initial decisions are assumed to be made separate from subsequent decisions. For example, in agricultural household models production decisions are thought to have no influence on the

decisions in consumption. In a recursive system the causality is one way and not interactive.

There is a notable difference in price elasticities derived from cross-sectional models that acknowledge the "profit effect" and those that do not. Table 1.1 presents household-based price elasticities from various studies in the literature with and without incorporation of the "profit effect." Note that in several instances the response elasticities changed not only magnitudes but also direction.

TABLE 1.1

AGRICULTURAL PRICE ELASTICITIES
WITH AND WITHOUT THE PROFIT EFFECT

	RESPONSE ELASTICITIES WITHOUT (A) AND WITH (B) THE PROFIT EFFECT					
COUNTRY	AGRICULTURAL COMMODITY		NON-AGRICULTURAL COMMODITY		LABOR SUPPLY	
	A	B	A	B	A	B
Taiwan	-0.72	0.22	0.13	1.18	0.21	-1.59
Malaysia	-0.04	0.38	-0.27	1.94	0.08	-0.57
Korea	-0.18	0.01	-0.19	0.81	0.03	-0.13
Japan	-0.87	-0.35	0.08	0.61	0.16	-1.00
Thailand	-0.82	-0.37	0.06	0.51	0.18	-0.62
Sierra Leone	-0.74	-0.66	-0.03	0.14	0.01	-0.09
Nigeria	-0.05	0.19	-0.14	0.57	0.03	-0.06

Adapted from Singh, Squire and Strauss, Agricultural Household Models, (1986) Table 1-2, pg. 26.

Layout of the Study

This first chapter begins with an introduction to the reason for studying agricultural household behavior and briefly describes the major characteristics of agricultural household models that integrate both production and consumption sides of household behavior. The clienteis for this research are identified followed by background information on Burkina's physical and socioeconomic setting that influenced data collection and interpretation. Finally, the data used to drive the model are described, although more detailed descriptions are available elsewhere.

A literature review reveals that agricultural household models have an extensive and international history with contributions from a variety of scholars and countries. The review points out that models have become increasingly more reflective of reality and that agricultural household models have been infrequently estimated due to the need for extensive data to support their estimation. The majority of models have been estimated from data on Southeast Asian countries. However, in spite of the extensive data demands of these models, their usefulness is in summarizing broad behavioral data within a consistent framework and increasing reflection of actual conditions in developing country agricultural household-firms. The literature review is presented in Chapter II.

Chapter III presents the theoretical model based upon the behavioral assumptions of utility and profit maximization. Under these conditions the addition of a "profit effect" is shown to make determination of household response to price changes indeterminate from theory. One must empirically estimate the behavior from primary data for a region or situation of interest. By also assuming a functional labor market, the resulting model can be shown to be recursive with production decisions preceding consumption decisions. A formal presentation of the recursive nature of the model is presented in the Appendix.

The results from estimating the production and consumption sides of the model are presented in Chapters IV and V, respectively. A Cobb-Douglas production function is used to estimate the supply side of the household while an Almost Ideal Demand System (AIDS) is used in estimating the demand side of household behavior. The results are more encouraging from the demand than the production side which directly reflects the quality and level of detail of the underlying data.

The presentation of the combined results of the production and consumption sides of the model are the focus of Chapter VI. In addition, implications for policy formulation in Burkina from this model are discussed. The work is completed by a discussion of possible avenues for future research relevant to understanding household level behavior.

Clientele for the Research

The clientele for more and better information on agricultural households begins with the countries themselves and the various policy arms of the government. Other interested parties for this kind of research may include bilateral and multilateral aid agencies. Private and voluntary organizations, which work directly with farming communities in developing countries, could also be interested in information on agricultural household behavior. These parochial interests should not cause us to overlook, or underemphasize, the purely intellectual appeal of modeling a complex phenomenon in order to better understand the world.

The Government of Burkina is the principal clientele for information on agricultural households in Burkina. A better understanding of the agricultural production and consumption behavior of agricultural households in Burkina will be of immediate assistance to planning and policy formulation. In most developing countries, agriculture provides income for the majority of the population, serves as a source of foreign exchange and a productive resource base for the rest of the economy. Without a good basis of information, the agricultural sector may not be utilized to its fullest capacity or may even be impeded by improper policy.

The specific users of this research would begin with the various policy arms of the government including, but not

limited to, the Ministry of Agriculture. Other interested parties may include bilateral or multilateral aid agencies and other African Governments. Other donor agencies and researchers could also be interested in information on agricultural household behavior in Burkina.

Background on Burkina

This section provides background information on Burkina that is particularly relevant to the interpretation of the results form the study. Two areas of information are identified that influenced the data collected and its analysis. An understanding of the conditions prevailing in Burkina in the physical and socioeconomic realms are important to a full appreciation of the research results and their limitations.

The most important physical factor influencing agricultural production in Burkina is the high variability of rainfall. This variability occurs across both space and time. Spatially, the south and southwest of the country are favored by more regular rainfall. Temporally the country has experienced periods of drought, with the most recent episodes during the agricultural seasons of 1983-84 and 1987-88. From a longer-term agroclimatological perspective the 1970s and 1980s were drier than the 1950s and 1960s.

Most agricultural production in Burkina is rain-fed and subject to the vegaries of these sahelian weather patterns. These patterns are characterized by highly localized and

uncertain rainfall that results in generally risky agroclimatic production zones. This risk generally increases as one moves from the south to the north of the country.

The four villages selected for study were chosen to cross these agroclimatic zones. Two villages were chosen in a chronically cereal production deficit zone, while the remaining two came from a transition zone that would normally experience surplus production. The two northwestern deficit villages, Méné and Bougoré, are located north and south of the town of Ouahigouya, respectively. The normally surplus villages in the west of the country are located north and south of the major regional town of Dédougou. Tissi is north of this regional capital and Dankui is located south of Dédougou.

The data used in this study are from calendar 1984 which captured the drought reduced agricultural production of 1983-84. Because of the drought, households in the sample were found to have been dominated by more net purchasers than sellers of cereals in the year from which data are available. In order to obtain sufficient cereals to meet their needs households interacted with the market more than would have been expected in a normal year. This was reflected in the data by reduced contributions of own agricultural production as a share of total cereals obtained (both produced and purchased).

Cereals are extremely important in the social and economic setting of Burkina. Consisting mostly of millet and sorghum, with some maize, wheat and rice, cereals compose from seventy to eighty percent of calories and sixty to seventy percent of proteins in the Burkina diet (Haggblade, 1984, p. 10). With just over nine million people, and a population growth rate of roughly three percent per year, Burkina has approximately thirty-two inhabitants per square kilometer. Gains in gross agricultural production in the 1980s have been achieved mostly by increasing the area under cultivation. Advanced agricultural technology and input use are limited with most farming households using land, labor, seed, rainfall and simple agricultural tools to produce a crop.

As mentioned earlier, the success of agricultural production is dependent upon the rainfall pattern. In order to diffuse agricultural production risk households have developed income diversification strategies. These strategies include diversification via trade, services, migration and mining, among other possibilities. Using Burkina data from approximately the same period as the present study, Reardon, Matlon and Delgado (1988) found households in the northernmost sections of Burkina which obtained only thirty percent of total household income from agriculture. Households in their sample were from villages slightly farther north than those used in the present study. However, similar

income and production diversification behavior in the face of risk was found among the households in the present study.

Data

An agricultural household model requires household production and consumption information, as well as market price data on commodities and labor. This is an extensive information requirement and few data sets are available to support this type of modeling. The data required are most frequently available in cross section. The data used in this study are from Burkina Faso and represent household transactions data on approximately 87 farm households from roughly the 1984 calendar year.

Originally part of a grain marketing study,[1] the data were collected in households from four villages in two different agroclimatic zones in Burkina. Two villages were from the sahelian northwest while the other two were from the western sudanian zone. After an initial village census of all households, samples were selected in a stratified random fashion by ethnic group. Household budget survey data were collected on a biweekly basis for twelve months. Interviewers lived in the villages, visited the households and interviewed all married inhabitants and those over

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[1] For a detailed presentation of the data instruments and setting from which these data originated, see May (1987).

eighteen years of age. A list of all the questionnaires used in the study is provided in Table 1.2.

The biweekly transactions data consisted of information on sales, purchases, consumption, amounts given (wages, gifts, taxes, etc.) and amounts received (salaries, remittances, gifts, etc.) by the household over the previous two weeks. Data on changes in household composition were collected on a monthly basis. Data collected on a quarterly basis included the livestock census and on-farm cereal storage. These two categories are important proxies for wealth in the sahelian agricultural household.

A one-time survey was also conducted to catalogue household durable goods as companion information on wealth stratification within the villages. Three additional questionnaires were administered on a one-time basis. First was the initial household census which, in addition to normal demographic variables, covered education, dependency status, and other sources of income. Second, a questionnaire was used to measure the physical area of household members' fields by crop. Third, the harvest was measured during the appropriate part of the agricultural year.

"Households" in Africa are not necessarily nuclear and in Burkina many household production and consumption units can be found within one family compound. In order to distinguish household units within the sample the census question-

TABLE 1.2

SUMMARY OF QUESTIONNAIRES

NAME	MAIN PURPOSE	FREQUENCY
VILLAGE CENSUS	establish village demographics for sample selection	ONCE
HOUSEHOLD CENSUS	sample household demographics	ONCE
FIELD MEASURES	area cultivated to each crop or crop mix	QUARTERLY
ON-FARM STORAGE	quantity of foodstuffs stored over time	YEARLY
HARVEST	harvest quantity	BIWEEKLY
CONSUMPTION	quantity and source of foodstuffs consumed	BIWEEKLY
SALES	quantity, value, good, reason and location of sale	BIWEEKLY
PURCHASES	quantity, value, good, reason and location of purchase	BIWEEKLY
AMOUNTS GIVEN	services, salaries, credit, gifts, and remittances given	BIWEEKLY
AMOUNTS RECEIVED	services, salaries, credit, gifts, and remittances received	BIWEEKLY
CHANGE IN HOUSEHOLD COMPOSITION	monitor household composition changes over time	MONTHLY
DURABLE GOODS	wealth and asset measures	ONCE
MEASURING UNITS	convert local measures to kilograms	ONCE
ANIMAL CENSUS	type, number and owner of livestock	QUARTERLY

naires were used in combination with household interviews to determine the appropriate composition of a decision-making unit. Among the criteria used to distinguish a separate household within a compound were common fields, granaries, and consumption and contiguous dwellings.

Information from the biweekly, monthly and annual survey questionnaires was used in estimating the model that follows. These data served to support the theoretical model presented in Chapter III and the estimates for the production and consumption sides of household behavior presented in Chapters IV and V, respectively. In addition to the analytics of the agricultural household model, a wealth of summary and descriptive information, as well as other economic inquiries concerning household behavior in Burkina, could be supported from this data. However, the following chapters are mainly concerned with the formal modeling of an agricultural household model to organize and interpret this large body of information on rural agricultural households in Burkina.

CHAPTER II
LITERATURE REVIEW

The interest and development of the theory of agricultural households has an international flavor with its beginnings in Imperial Russia, mathematical specification in Japan, and empirical verification in the United States. The idea of recording and studying the actual behavior of peasant farmers began in Russia in the 1880s with the advent of reforms under Alexander I. This highly detailed examination of farm life in pre-Revolutionary Russia formed the basis of inquiry on agricultural households by A.V. Chayanov.

Nakajima, working and publishing mostly in Japan, was the first to work out a neoclassical framework and the comparative statics for the family farm. Although his work was mainly theoretical, Nakajima's writings provided the basis for the testing, modification and subsequent refinement of agricultural household models.

The empirical estimation of agricultural household models began in the mid-1970s with most of the work coming from the Food Research Institute at Stanford University. Lau and Yotopoulos, working with other scholars from Southeast

Asia, presented a series of articles using household-based studies of agriculture in Taiwan and Thailand.

More recently, in the 1980s, agricultural household models have become a useful analytical technique for examining cross-sectional data in developing country agriculture. The World Bank sponsored volume, edited by Singh, Squire, and Strauss (1986), has become the standard volume on agricultural household models. Further developments and concerns about these models are now being expressed in the economic literature on developing country agriculture.

Chayanov

The seminal work on agricultural household models is that of Alexander Vasilyvich Chayanov on peasant agriculture in pre-Revolutionary Russia (Chayanov 1966, 1986). Chayanov based his theory of the family farm on extensive data collected from regional- and district-level surveys of peasant households after the serfs were emancipated and land reform enacted in 1861.

Chayanov held that agricultural households were unique economic units in that the household "firm" provided the bulk of its needed production inputs (principally labor) while at the same time consuming the bulk of its own production. Because such firms provided their own inputs and consumed what they themselves produced, the impact of their decisions might be different from those expected from the

neoclassical theory of the firm.[2] As mentioned in the introduction, in a household that produces what it consumes the income effect can cause the nature of household responsiveness to be indeterminate from theory.

The writings of Chayanov only became available to an English-speaking audience in 1966, but were known to scholars in other parts of the world through earlier translations in German and Japanese. Nakajima cites his exposure to Tschajanow's (sic) writings as an early influence on his subsequent writings about the agricultural household (Wharton, 1969, p. 165). The introduction to Shanin's reissue of Chayanov's writings states that "the impact of the implicit cross-influences cannot be ascertained, but the views of Chayanov and his friends spread fairly broadly through Europe and Asia via the German professional literature of the 1920s (Chayanov, 1986, p. 11)."

Chayanov focused his analysis on those households which used little or no labor, other than that provided by the household itself. He formally defined a "family farm" as an economic unit that normally employed no wage labor in its production process. Because the Chayanovian "family farm" used family labor almost exclusively, wage rates could not be determined and hence profits were indeterminate.

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[2] However, it can be explained through a constrained optimization model in the neoclassical mode as will be presented in this research.

With profits indeterminable, Chayanov proposed a decision rule for the "family farm" that differed from profit maximization. He suggested that the "family farm" equates the satisfaction of family needs with the drudgery of work required. From his intense familiarity with Russian peasant agriculture, Chayanov realized that Russian peasants did not work to achieve profit maximization. Their labor supply and efficiency did not coincide with profit maximizing behavior as they could almost always provide additional labor or work harder but chose not to do so.

Chayanov worked towards producing a separate theory of the "family farm" that would have its own unique analytical techniques. From his labor-consumer balance, equating the drudgery of work to the consumption needs of the household, he concluded that each household would find its own subjective equilibrium. The level of this balance would be influenced by the size of the family and its ratio of working to non-working members.

The "family farm" had a certain resiliency or survival power that the capitalist farm did not. Peasant farms could continue to survive in an environment that would bankrupt capitalist farms or socialist collective farms. They would do so by working longer hours or selling at lower prices, even continuing from year to year yielding no net surplus production. Such behavior required a unique form of analysis

of farm household behavior because it could not be adequately explained by existing theoretical constructs.

He also commented on a "natural history" of the household which can be likened to the "life cycle" income theory. For Chayanov this "demographic differentiation" of households was more important in determining their behavior than class differentiation. This idea and others about transforming Russia agriculture would eventually lead Chayanov into conflict with the revolutionaries of post-1917 Russia.

For Chayanov the household economy, although distinctly different from other analytical economic paradigms, exists within and is influenced by the prevailing economic system, be it capitalist or collective. However, the household would incorporate and adapt to its environment while at the same time retaining its conceptual uniqueness and calling for separate analysis. Unfortunately, the complete ramifications of Chayanov's separate economic theory of the agricultural household were never fully expounded as he was caught up in the Stalinist purges and agricultural collectivization of the 1930s and eventually died in 1939 at the age of fifty-one.

Nakajima

Chahiro Nakajima mathematically formalized the work of Chayanov by expounding on the subjective equilibrium of

agricultural households.[3] The Japanese audience was familiar with the writings of Chayanov at an earlier date than the anglophone audience. Nakajima's work, which itself only became available to a wide anglophone audience in 1969 (Wharton, 1969) allowed for a continuum of households, from those consuming all of their own production and providing all of their labor input (subsistence farms) to those consuming none of their production and purchasing all their labor (commercial farms).

Nakajima's classification of the world's diverse agricultural production systems along a continuum can be viewed as having two dimensions, consisting of the level of own production consumed by the household and the level of own labor provided by the household. At one extreme was the purely subsistence household consuming all of its own production and providing all of its own labor input. At the other extreme of his continuum was the purely commercial farm which sold all its output and purchased all of its labor input. Nakajima commented that the later extreme was "rarely found" and the former was a "very small percentage" of world farms (Wharton, 1969, p. 165). He clearly recognized that the bulk of the world's farms fall somewhere between these two extremes.

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[3] "Subjective" because each household can have its own utility function which is maximized subject to an income constraint.

In order to capture the diversity of farm production possibilities, Nakajima proposed four models of household behavior. Two models examined the behavior of the pure commercial family farm while two captured the behavior of the semisubsistence or semicommercial family farm. The purely commercial farm models were distinguished by the presence or absence of a competitive labor market. For the pure commercial family farm with a competitive labor market Nakajima noted that this "family farm may be regarded as an economic unit which behaves, in the first phase, as a 'firm' maximizing profit and, in the second phase, as a laborer's household with nonlabor income maximizing utility (Wharton, 1969, p. 180)." This is the first mention in the literature of what has come to be known as the recursive nature of the agricultural household decision-making process.

In deriving the comparative statics for the purely commercial farm models, Nakajima introduced inputs other than fixed land and variable labor. Nakajima examines the impact of fertilizer as another factor of production whose price is determined in a competitive market. He also allows for the addition of multiple outputs in his purely commercial family farm models.

Turning to the two semisubsistence (or semicommercial) models, Nakajima assumed that these households did not have access to a labor market, but were distinguished by having single or multiple output crops. In these models the house-

hold provided all of its own labor requirements and consumed some of its own production.

In each of the four cases proposed by Nakajima he solves for the comparative statics under the assumption of utility maximization. He thus obtains the first-order conditions and equilibrium values of each of the variables in the respective models. He examines the impact of changes in asset income, output price, and family size as well as the effects of technology and seasonality on the comparative statics.

Nakajima's work provided, in addition to his continuum classification and comparative statics, the introduction of a labor market to the theory of the agricultural household. Contrary to Chayanov, Nakajima allowed for the possibility of a labor market exchange by the household. He introduced a market from which the household could obtain or provide labor at a fixed wage rate. Nakajima's work has received renewed attention through the recent publication of a collection of his writings on the subjective equilibrium of the household (Nakajima, 1986).

Lau, Yotopoulos, and Others

The work of Chayanov and Nakajima was empirically embellished by researchers at the Food Research Institute at Stanford, with support from the World Bank and the Ford Foundation. This research, published principally in the

1970s, focused on the empirical workings of the agricultural household theory developed by Chayanov and Nakajima. Data were obtained on the agricultural household economies of two Southeast Asian nations, Taiwan and Thailand.

However, there are notable differences between the empirical approach of Lau, Yotopoulos, et al., and Chayanov. In the two Southeast Asian production studies they assume profit maximization by the agricultural household, which runs counter to Chayanov's argument that peasant families, particularly in pre-Revolutionary Russia, do not maximize profits.

When the separate studies of production and consumption that follow are combined they yield a complete system estimation for agricultural households. The system is complete in the sense that input demand and output supply equations are estimated for the production side, while commodity demand equations are estimated for the consumption side of agricultural household behavior.

Production in Taiwan

Lau and Yotopoulos, along with Lin (Yotopoulos, Lau, and Lin, 1976), first began their examination of agricultural households with cross-section data from Taiwan. Modeling the production behavior of Taiwanese agricultural households, they assumed a Cobb-Douglas production function and utilized a profit function to describe the underlying

technology. This profit function was normalized by output price and specified as being log linear. The profit function was also considered to be "restricted" because it measured current revenue minus current variable costs.

From the Taiwan household data these researchers determined four variable inputs (labor, animal labor, mechanical labor, and fertilizer) and two fixed inputs (land and fixed assets). Input demand and output supply equations were derived from the Normalized Restricted Profit (NRP) function via Hotelling's Lemma. The method of estimation used was Zellner's seemingly unrelated regression, because it is asymptotically efficient for systems of equations that have related error terms (Zellner, 1962).

In this first of many studies on agricultural households, Lau, Yotopoulos and Lin tested for profit maximization and constant returns to scale in production. On the basis of their results they were not able to reject the hypothesis of profit maximizing behavior by Taiwanese agricultural households. Contingent upon profit maximization, they were also unable to reject the hypothesis of constant returns to scale in Taiwanese agriculture.

Consumption in Taiwan

Following their earlier work in 1976 on the production behavior of Taiwanese agricultural households, Lau, Yotopoulos and Lin turned to consumption behavior (Lau, Lin and

Yotopoulos, 1978). Assuming utility maximization by the household, these researchers employed an indirect utility function to analyze the consumption behavior of agricultural households.

Utilizing a linear logarithmic expenditure system (LLES) they estimated commodity expenditure equations derived from a transcendental logarithmic (henceforth, translog) indirect utility function that is homogeneous of degree one in prices. The commodity expenditure equations for three aggregated commodities (agricultural commodities, non-agricultural commodities and leisure) were derived via Roy's Identity. Household characteristics, such as the size and composition of the household, were included as arguments in the indirect utility function.

The translog indirect utility function is assumed to be homogenous of degree minus one. One implication of this assumption, for both the Taiwanese and subsequent Thai consumption analysis, is that the total expenditure elasticity of demand for each commodity is identically equal to one.[4]

Elasticities for consumption demand, labor supply and marketed surplus with respect to prices, incomes, household composition and household endowment were derived from the

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[4] This, of course, not does not imply that income elasticities are identically one, because the imputed value of leisure is included as part of total expenditure in these studies.

results of the seemingly unrelated regression equations (again using Zellner's method). The hypothesis of utility maximization by Taiwanese households could not be rejected.

Production parameters, such as agricultural output supply, necessary for the estimation of household income and marketed surplus, were taken from the previous work on Taiwanese production by the same authors. The reader will recall that the output supply was determined using a normalized restricted profit function and Hotalling's Lemma. This profit function has no arguments based upon an underlying preference structure expressed in a utility function. Thus, the production decisions are implicitly assumed to be separable from the consumption decisions. However, because the output supply affects income, consumption decisions are influenced by production decisions.

Production in Thailand

After completing studies on production and consumption behavior in Taiwanese agricultural households, Lau and Yotopoulos turned to the analysis of data from Thailand. Working with other scholars from Japan (Kuroda) and Thailand (Adulavidhaya and Lerttamrab), they examined the production characteristics of Thai households (Adulavidhaya, Kuroda, Lau, Lerttamrab and Yotopoulos, 1979). A Normalized Restricted Profit function was again employed from which they derived input demand and output supply equations with four

variable inputs (labor, animal input, mechanical input, fertilizer and seed) and two fixed inputs (land and capital assets). All prices were normalized by output price.

The functional form used was log linear and estimation was by ordinary least squares. They tested for both profit maximization and constant returns to scale, as in the case of Taiwan, with similar results; neither hypothesis could be rejected. A further result was that both factor demand and output supply were sensitive to changes in output price.

Clearly, the work on the Thai data was quite similar to that using the Taiwanese data, but it was reassuring to find that both profit maximization and constant returns to scale held in the two different environments. The authors foretell their future plans for this data when they state that "the next step of the analysis of the Thailand data . . . also combines the consumption side of the agricultural household (Adulavidhaya, Kuroda, Lau, Lerttamrab and Yotopoulos, 1979, p. 85).

Consumption in Thailand

The consumption analysis of Thai agricultural household data proceeded along the same lines as that outlined for the Taiwanese data (Adulavidhaya, Kuroda, Lau and Yotopoulos, 1984). Utilizing a linear logarithmic expenditure system under the assumption of utility maximization, they described an indirect utility function. Specifying a translog func-

tional form for the indirect utility function, household commodity expenditure equations for agricultural commodities, non-agricultural commodities and leisure were derived using Roy's Identity. These three aggregated commodities were deemed important for the analysis of the supply of marketed surplus, the demand for non-agricultural commodities in the agricultural sector, and the income-leisure choice and supply of labor, respectively.

As in the Taiwanese consumption study, homogeneity was assumed, with its subsequent implications, and the estimation technique was Zellner's seemingly unrelated regression analysis. Output supply was taken directly from the earlier study on Thai production which used a normalized restricted profit function. Like the earlier Taiwan study, the Thailand consumption study is different from the traditional Engel curve analysis because of the introduction of family composition information as an independent variable in the utility function. However, in contrast to the earlier Taiwanese study, utility maximization by Thai agricultural households was rejected.

Implicit in each of the consumption analyses performed by Lau, Yotopoulos, et al., in both Taiwan and Thailand, is the separability of the production and consumption decisions of the household. The production analyses, in both cases, can stand on their own without further caveats. However, the consumption analysis, with household income partially

determined through the profit function, and hence the underlying production technology, is dependent upon the production decisions of the household. The production decisions influence the consumption decisions, but the production decisions are independent of the consumption decisions.

It is clear from the work of Lau, Yotopoulos and associates that the beginnings of an integrated theoretical framework for the analysis of agricultural households were possible. Heretofore, researchers would focus one entry in the literature on the production side of the household followed by a sequel, the analysis of the consumption side, utilizing the results from the earlier production study. It was now time for a consistent theoretical framework within which to specify agricultural household models for developing countries.

Barnum and Squire

Barnum and Squire, in contrast with the earlier studies outlined above, were the first researchers to incorporate both production and consumption aspects of the household in one paper (Barnum and Squire, 1979a, 1979b). This team of researchers also used cross-sectional agricultural household data from a Southeast Asian country: the Muda River Valley in northwest Malaysia. They were also working in an essen-

tially monocultural agricultural environment as in the previous studies of rice-based agricultural economies.

Although Barnum and Squire used the same theoretical foundation as Lau, Yotopoulos and associates, there were differences in the choice of functional form between the two teams. In contrast to the latter's profit function approach to the production side of the problem, Barnum and Squire preferred to directly estimate the production technology. They chose to estimate a Cobb-Douglas specification for the production technology and then derive the profit function and input demand equations.

On the consumption side they were more concerned with the restrictions involved in the Linear Logarithmic Expenditure System utilized by Lau, Yotopoulos and associates, especially the constrained nature of the expenditure elasticities. They employed a modified Linear Expenditure System which, unlike the LLES, did not require that all expenditure elasticities equal one. However, even with this more flexible functional form, the own price elasticities were restricted to be linearly related to the expenditure elasticities. The LES is derived from the Stone-Geary additive utility function.

Of particular interest to Barnum and Squire was the impact of the analytical framework of agricultural household models on migration, marketed surplus, technology and the demand for hired labor. They found that the cost of migra-

tion was low relative to the marginal productivity of an agricultural laborer, that marketed surplus was not responsive to output price changes, and that increases in output price and technology would positively influence rural wages, thereby having a favorable impact on rural workers dependant upon wage labor.

In spite of the different functional forms used in the estimations of Barnum and Squire versus Lau, Yotopoulos and associates, the outcomes were reasonable. Their elasticities were similar enough with those of Lau, Lin and Yotopoulos to prompt Barnum and Squire to remark on the similarity of preferences for Taiwanese and Malaysian agricultural households (Barnum and Squire, 1979b, p. 77).

As a follow-up, Tamin used Barnum and Squire's data set and a log-linear Cobb-Douglas functional form of a normalized restricted profit function, with four variable inputs and two fixed inputs, to model the production behavior of a cross section of Muda River Valley households (Tamin, 1979). Joint estimation, by Zellner's seemingly unrelated regressions, of the profit function and four factor share equations was undertaken with and without restrictions imposed. Estimation without restrictions allowed hypothesis tests for profit maximization and constant returns to scale, neither of which could be rejected.

Tamin found low own-price elasticities of output supply as well as low fertilizer price elasticities of output

supply. He also tested for technical and price efficiency differences between owner-farm households and tenant-farm households with no significant differences in efficiency found.

Singh, Squire and Strauss

The empirical embellishments and refinements on agricultural household models continued throughout the early 1980s. A collection and synthesis of these works was brought together in 1986 under the editorship of Singh, Squire and Strauss (1986). With introductory chapters on the theory of agricultural household models, these writers then presented nine case studies by different authors, including the editors, that utilized the basic framework of a separable, or recursive, agricultural household model.

These models can be characterized as standard optimization problems. The household is assumed to maximize a joint household utility function subject to constraints. There are generally three constraints on the household's decision-making process. Utility is maximized subject to budget, time and technology constraints. Prices are assumed to be given in both input and output markets. Such models can be shown to be recursive.[5]

[5] See the Appendix to this study for a rigorous presentation of the recursivity of agricultural household models.

Exceptions to this model are the chapters by Roe and Graham-Tomasi, and Lopez (see also Lopez, 1984) included in the case studies, both of which bring into question the recursivity assumption of this neoclassical model of agricultural households. Roe and Graham-Tomasi bring risk into the household decision-making process and find that the original neoclassical results will only hold under what can be considered severe restricting assumptions (Singh, Squire and Strauss, 1986). Lopez (1984; Singh, Squire and Strauss, 1986) shows that the recursivity will not hold if the household is not indifferent between on-farm and off-farm labor, both in the sense of labor hired and labor supplied. Lopez's work is also important in emphasizing that this literature on agricultural household models is not limited to the study of developing country agriculture, but is also useful in describing agriculture in more industrial nations, in this case Canada.

The remaining seven case studies utilize the basic model with recursivity intact. Two of the case studies can be considered as complete systems analyses in the tradition of Lau, Yotopoulos, et al., and Barnum and Squire. Singh and Subramanian (Singh, Squire and Strauss, 1986), using data from Korea and Nigeria, model consumption decisions with a Linear Expenditure System while the production side employs a linear program. Their study is characterized by additional commodity disaggregation and multiple crops. Strauss (Singh,

Squire and Strauss, 1986) examines households in Sierra Leone to determine the impact of pricing policies on nutritional status, measured as calorie intake. He employs a Quadratic Expenditure System (QES) to determine consumption parameters and a multiple output production function to model the production decisions. In his QES, outputs are related via a constant elasticity of transformation and inputs are linked via a Cobb-Douglas production function.

Using data from Indonesia, Pitt and Rosenweig (Singh, Squire and Strauss, 1986) take Strauss' concern for nutritional effects further to determine impacts on health and from health to labor productivity. Smith and Strauss (Singh, Squire and Strauss, 1986) turn to distributional issues and examine the impacts of price policy on different segments of the rural population in Sierra Leone within the structure of an agricultural household model. Bravarman and Hammar (Singh, Squire and Strauss, 1986), with disaggregated commodity data from Senegal, bring the agricultural household model into General Equilibrium analysis. In their model markets clear through import and export adjustments in international trade.

Iqbal (Singh, Squire and Strauss, 1986) examines household borrowing in India by introducing the credit market into the basic model with a two-period model. Finally, Siculer (Singh, Squire and Strauss, 1986) takes a novel approach by using a programming variant of the general

agricultural household model to examine the influence of centrally planned quotas and restrictions on Chinese production teams. With these case studies, and the introductory chapters, the editorial work of Singh, Squire and Strauss (1986) provides a rich source of theoretical and empirical work concerning agricultural household models.

<u>Haughton</u>

Haughton stresses the importance of choosing an appropriate functional form for the production function in estimating agricultural household models (Haughton, 1986). He argues that without a theoretically sound specification of a production function the more sophisticated agricultural household models are of little use. The same can be said for the specification of the consumption function. Lopez also stresses the importance of using flexible functional forms in modeling agricultural household models to ensure the minimum amount of restrictions on behavior (Lopez, 1984, p. 62).

In Haughton's study, employing cross-sectional data from western Malaysia (yet another study using data from Southeast Asia), he compares the results from the same data set of different functional forms to represent the underlying production technology of the household. Quantity-based translog and Cobb-Douglas production functions are compared

with indirect, normalized price-based translog and quadratic restricted profit functions.[6]

While citing the differing results obtained by Barnum and Squire versus Tamin on the same Muda Valley data set, Haughton also points out sources of variation, other than functional form, that may influence the empirical measurement of agricultural household response to price changes. First, differences may depend on whether or not the researcher models a single crop as output or derives some total farm output figure. Secondly, data may be from different time periods or regions (not the case in the Muda Valley studies). Finally, how variables are defined, lagged, or chosen for exclusion due to lack of data can influence the results of estimations.

In testing the direct production estimates, Haughton found that in general, "the Cobb-Douglas form is not sustained (Haughton, 1986, p. 213)." However, he goes on to state that "the superiority of a homogenous translog form should not be overstated" (Haughton, 1986, p. 213) principally because both forms gave similar output elasticities. He concludes by arguing that the choice of functional form will depend upon the particular constraints of the available data.

[6] Recall that the Cobb-Douglas production function is a special case of the more general translog production function.

His results from the translog and Cobb-Douglas restricted profit functions were "disappointing." The share equations were not significant and the estimation was a poor fit. He cites the difficulty in measuring restricted profits because they are a residual and tend to magnify data errors. The choice of how to value on-farm family labor is also cited as a source of these poor results. Recall that it was this same problem which caused Chayanov to conclude that the neoclassical approach to the analysis of agricultural households was inadequate.

Haughton proposed a third possibility, the direct estimation of input demand and output supply equations derived from restricted profit functions, of which the normalized quadratic restricted profit function appeared to be the most promising. This, of course, will require more close attention to the collection of valid price data, in addition to quantities, in the developing country context.

Bezuneh, Deaton and Norton

Bezuneh, Deaton and Norton (henceforth, BDN) used an agricultural household model approach to examine the various impacts of food aid under a Food-For-Work (FFW) scheme in the Baringo District of Kenya (Bezuneh, Deaton and Norton, 1988). They chose to model the production side of the household with a linear programming (LP) approach and the consumption side with an Almost Ideal Demand System (AIDS).

By their choice of an LP model on the production side BDN argue that they can disaggregate commodities (96 activities and 82 constraints), examine the impact of FFW-based capital investment and limit the cost of data collection needed to support the model. The argument for using an AIDS model on the consumption side is that it allows for flexible price and income elasticities. BDN use the linear approximate Stone price index and impose the standard demand conditions of adding-up, homogeneity and symmetry when estimating the AIDS model using an iterative nonlinear Zellner method for seven commodities.

The FFW enters the model directly through a second (after farm household) production function for obtaining FFW commodities. They also attempt to include a static, two-period production component in an attempt to capture investment effects of FFW programs. Another interesting addition by BDN is the incorporation of a minimum consumption requirement resulting in nonseparability between production and consumption decisions. A household that perceives a minimum consumption need will base that perception on the household consumption needs which would then impact production decisions.

The authors found that FFW increased production, income, capital investment, employment and marketed surplus in the Baringo District. A shift from maize to millet production was attributed to the maize distributed as FFW

meeting consumption needs and millet being a more profitable crop. Own price elasticities of demand were negative, as would normally be expected except for the combined millet and sorghum good. The positive own-price elasticity was attributed to the profit effect because a higher price would result in higher incomes, particularly among households participating in the FFW program.

CHAPTER III
THEORY OF THE AGRICULTURAL HOUSEHOLD

Introduction

The agricultural household in a developing country is unique for three major reasons. First, the agricultural household consumes a major part of its own production. The food crops produced in an agricultural household are partly consumed by that household while some is marketed to provide income. Other types of households do not generally consume part of that which they produce. Hence, in an agricultural household the output of the "firm" can greatly influence consumption choices, or levels, via income.

The second reason why agricultural households are distinctly different from other households is that they provide their own labor as a major part of the inputs used in the production process. The combination of being the major provider of inputs and the major consumer of output allows for the possibility of unique behavior on the part of an agricultural household. In this chapter we will outline a general theory of this type of agricultural household.

The third distinguishing characteristic of agricultural households in developing countries is the nature of the

management process. For example, in a developing country management techniques and practices may involve the use of multiple households acting as one unit, sources of income may be determined by kinship patterns, and cultural practices and preferences may influence choices.

The problem of theoretically modelling an agricultural household can be framed in the standard techniques of constrained optimization. The household can be assumed to optimize an objective function, in this case utility, subject to a series of constraints. These constraints generally include information concerning the limitations on behavior due to income, time, and technology.

The General Theory of an Agricultural Household

The general model used in this study can be succinctly written as a constrained optimization problem as follows:

$$\text{MAX } U = U(X_a, X_m, X_l) \tag{3.1}$$

subject to:

$$\text{(i) } P_a X_a + P_m X_m + w(L-F) \leq P_a Q$$

$$\text{(ii) } X_l + F = T$$

$$\text{(iii) } Q = Q(L, A)$$

maximizing utility subject to constraints due to income (i), time (ii), and technology (iii), respectively. The goods consumed are the crop produced by the household, X_a; goods purchased on the market, X_m; and the leisure time available

to the household, X_l. Prices for goods and services are the price of the agricultural commodity, P_a, market commodities, P_m, and wages, w. Total time, T, is allocated to agricultural labor supplied by the household, F, and leisure, X_l. Agricultural output, Q, is the product of total labor (L) and land, A.

Leisure time is broadly defined in this model to incorporate any activity undertaken by the household that is related to own agricultural production. This is a key point in analyzing the behavior of sahelian agriculturalists. Recent studies have found that as much as seventy percent of total household income in extremely risky agroclimatic zones comes from non-agricultural production (Reardon, Matlon and Delgado, 1988 and Staatz, D'Agostino and Sundberg, 1990). In this model the diversified income strategy in response to agricultural risk is captured as exogenous income.

The Utility Function

The agricultural household is assumed to function under a joint utility function for the household as a distinct unit. In this particular theory there is no concern for the intrahousehold distribution of resources. Although such distributional issues are important (see Folbre, 1986), the data from which the model will be estimated is not sufficiently disaggregated to allow examination of the issues concerning intrahousehold distribution. Thus, the model will

assume a joint utility function for the household. A utility function which, when maximized for the household unit as a whole, is assumed to maximize utility for its individual members.

Household utility maximization is assumed to be a function of the goods consumed by the household. In this case, the goods consumed are the crop produced by the household, goods purchased on the market, and the leisure time available to the household. The resulting utility function is:

$$U = U(X_a, X_m, X_l) \qquad (3.2)$$

with X_a a vector of agricultural goods, X_m a vector of market goods, and X_l the leisure consumed by the household.

The utility function is assumed to behave in accordance with standard theory. It is considered to be quasi-concave in its arguments and its partial derivatives are positive. Of course, the quantities appearing as arguments in the utility function are assumed to be nonnegative. Other household characteristics can be added as arguments in this utility function. Examples include number of dependents, level of education, and other socioeconomic factors.

<u>The Income Constraint</u>

As outlined above, this optimization is subject to certain constraints. In the general agricultural household model the objective function is constrained by three re-

strictions on the household's actions. The first constraint can be written such that the household expenditures are less than or equal to the income available to the household, or

$$P_aX_a + P_mX_m + w(L-F) \le P_aQ. \qquad (3.3)$$

The inequality holds due to possible zero level expenditures or savings by the household. Household consumption consists of expenditures on agricultural goods, P_aX_a; market goods, P_mX_m and expenditure on hired agricultural labor, $w(L-F)$.

The quantity of agricultural labor hired by the household is the difference between total labor input on the farm (L) and the total quantity of labor, on and off-farm, supplied by the household (F). Here, wage rates are assumed equivalent between on-farm and off-farm labor implying that the household is indifferent between these two types of labor. The household income is derived from agricultural goods whose quantity, Q, represents gross production. Subsequently, the value of agricultural goods sold by the household, P_aQ, represents agriculturally based income.

It is interesting and instructive to note that the term $w(L-F)$ may appear on either side of the income constraint. In other words, it may be construed as either an expenditure or an income term. This is due to the expression $(L-F)$ which can be either positive or negative. If total labor input, L, is greater than that supplied by the family, F, then the expression is positive and the farm household employs labor from off-farm to make up the difference. In this case the

expression $w(L-F)$, the value of the employed labor, is interpreted as an expenditure and employed on the left-hand side of equation 3.3.

On the other hand, if family labor supplied, F, is greater than the total labor input, L, then the expression $(L-F)$ is negative and the household is supplying labor to the off-farm market. The value term $w(L-F)$ is then interpreted as the return to off-farm labor supplied by the household and is counted as an addition to income. In formal specification of the income constraint equation the labor value term would be subtracted from other right-hand side terms to ensure that the "negative" quantity $(L-F)$ is positively valued.

The Time Constraint

The household has the opportunity of utilizing its total endowment of time in either leisure or labor. Therefore, the sum of the amount of time spent in leisure, X_l, and that spent in family labor input, F, must be equal to the total time available, T. In equational form this gives the identity:

$$X_l + F \equiv T. \tag{3.4}$$

This equality holds if one assumes that all slack time is leisure. However, if some slack time is considered lost due to illness, weather or other factors then the equality becomes an inequality (less than or equal).

Other possible behavioral characteristics could be modeled through the time constraint. One example is the inclusion of a cultural variable, C, that reflects the minimum amount of time devoted by the household to community or cultural activities. Not all leisure time is devoted to cultural activities, thus $X_l \geq C$.

<u>The Technology Constraint</u>

The technology constraint represents the production technology that is employed by the household in combining inputs to produce output. A general production function can be used to represent this underlying technology and is written as:

$$Q = Q(L,A) \tag{3.5}$$

where L is variable labor input and A is the fixed area under cultivation. This production function is assumed to be quasi-convex and increasing in inputs.

<u>Combining Constraints to Yield the Full Income Constraint</u>

The three constraints outlined above can be combined into one constraint in order to simplify the problem. Substituting both the time and technology constraints into the income constraint and rearranging gives:

$$Y = P_a X_a + P_m X_m + wX_l \leq P_a Q(L,A) - wL + wT \tag{3.6}$$

which can be interpreted as a variant on Becker's "full income" (Becker, 1965).

The expenditure side of the household's "full income" constraint is now augmented by the value of the household's leisure time, wX_l. The income side consists of the value of agricultural production, $P_aQ(L,A)$, the value of the household's entitlement of time, wT, and is diminished by the value of total labor utilized by the farm, wL. Note that the value of agriculturally based gross income can be given by $[P_aQ(L,A)-P_aX_a]$. This can also be interpreted as the value of marketed surplus, where $P_aQ(L,A)$ is the value of gross agricultural production of the household and P_aX_a the value of agricultural goods consumed by the household.[1]

Note that the full income constraint in the agricultural household model contains an element of income whose value is generated using the household's production technology. The combined term, $P_aQ(L,A) - wL$, on the income side of the "full income" constraint, represents household profits from agricultural activity. These profits, π, can be written as:

$$\pi = P_aQ(L,A) - wL \tag{3.7}$$

and could be determined via a profit function that can be specified so as to be representative of the underlying technology employed by the household.

While the optimization problem is still framed as a consumption problem in which the household is assumed to

[1] This assumes that all agricultural goods not consumed by the household are sold on the market and not given away in non-market exchanges which may not always be the case.

maximize utility, one can begin to see how the production decisions may, in fact, influence consumption decisions through the income term in the full income constraint.

Solving the General Model

With the substitutions and rearrangements of the income constraint outlined in the previous section, the original optimization problem can be restated as:

$$\text{MAX } U = U(X_a, X_m, X_l) \tag{3.8}$$

subject to:

$$\text{(i) } P_aX_a + P_mX_m + wX_l \leq wT + P_aQ(L,\bar{A}) - wL.$$

The agricultural household has choice variables concerning the amount of agricultural goods to consume (X_a), amount of market goods to consume (X_m), amount of leisure to consume (X_l), and total labor input supplied to the farm (L), assuming that acreage under cultivation is fixed ($\bar{A}$). The household, under the assumption of utility maximization, will seek to optimize the levels of these four choice variables.

Kuhn-Tucker Conditions

In its most general form this model consists of a nonlinear objective function subject to a nonlinear constraint. The solution to a nonlinear programming model is described by the Kuhn-Tucker conditions which consist of

marginal, non-negativity and complementary slackness components (Intrlligator, 1971, p. 49).

Write the generalized Lagrangian function as:

$$\Phi = U(X_a, X_m, X_l) + \mu(Y^* - P_m X_m - P_a X_a - wX_l) \qquad (3.9)$$

where μ is the Lagrangian multiplier and Y^* is the value of full income that results from profit maximizing behavior such that:

$$Y^* = wT + P_a Q(L^*, \bar{A}) - Wl^* \geq P_m X_m + P_a X_a + wX_l \qquad (3.10)$$

$$= wT + \pi^*(P_a, w, \bar{A})$$

where L^* is the labor input level under the assumptions of maximized profits, π^*, and fixed area under cultivation, A. Note that, consistent with duality theory, the underlying production technology can be modeled either via a production function, Q(.), or an indirect profit function, $\pi^*(.)$.

The Kuhn-Tucker marginal conditions at the point of the optimum (X_a^*, X_m^*, X_l^*, μ^*) are:

$$\partial\Phi/\partial X_a^* = \partial U/\partial X_a^* - \mu P_a \leq 0 \qquad (3.11)$$

$$\partial\Phi/\partial X_m^* = \partial U/\partial X_m^* - \mu P_m \leq 0$$

$$\partial\Phi/\partial X_l^* = \partial U/\partial X_l^* - \mu w \leq 0$$

$$\partial\Phi/\partial \mu^* = Y^* - P_m X_m^* - P_a X_a^* - wX_l^* \geq 0$$

The Kuhn-Tucker non-negativity conditions state that

$$X_a^* \geq 0, \quad X_m^* \geq 0, \quad X_l^* \geq 0, \quad \mu^* \geq 0 \qquad (3.12)$$

thus the choice variables and the multiplier are all limited to the non-negative orthant. The multiplier, μ, is the marginal utility of full income.

The Kuhn-Tucker complementary slackness conditions given by:

$$(\partial\Phi/\partial X_a^*)(X_a^*) = 0 \qquad (3.13)$$
$$(\partial\Phi/\partial X_m^*)(X_m^*) = 0$$
$$(\partial\Phi/\partial X_l^*)(X_l^*) = 0$$
$$(\partial\Phi/\partial\mu^*)(\mu^*) = 0$$

serve to emphasize the possibility that an interior solution, where the first order partial derivative of the objective function must equal zero, may not exist. However, whether the solution occurs at a boundary or an interior point, the complementary slackness condition states that the choice variables or the first order partial, or both, must be equal to zero.

The marginal conditions of equation 3.11 involve four equations and four unknowns and, if all are binding as one would expect in this model, can be solved to give the demand equations for the three choice variables.[2] These demand equations can be written as:

$$X_i = X_i^*(P_a, P_m, w, Y^*) \qquad i = a, m, l \qquad (3.14)$$

which is the neoclassical result that demand is dependent upon prices and income.

However, in an agricultural household the full income variable, Y^*, is determined by the household's production

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[2] One would expect all conditions to be binding since X_a^*, X_m^*, X_l^*, and μ^* would all be expected to be positive in a smallholder household, therefore equation 3.13 suggests that equality hold in each equation 3.11.

technology through equation 3.10. In equation 3.10 the only endogenous variable utilized in the characterization of the production technology is total labor, L. Thus, production decisions are made separate from consumption decisions; they are separable decisions. The recursive nature of the model becomes evident as consumption decisions are seen to be dependent upon production decisions, but not vice versa.[3]

Profit Effect

The major result of the agricultural household model is the introduction of the profit effect. As outlined in the Introduction, the profit effect can counterbalance traditional neoclassical theory of household behavior with respect to price changes. This section outlines an example of the profit effect through an increase in output price and its implications for consumption.

The total change in quantity demanded, dX_a, with a change in output price, dP_a, can be determined by totally differentiating the appropriate demand equation. Totally differentiate the demand for the agricultural good (equation 3.14) and divide by the change in its own-price, assuming that the prices of market goods and wages are exogenous, to give

$$dX_a/dP_a = \partial X_a/\partial P_a + (\partial X_a/\partial Y^*)(dY^*/dP_a) \qquad (3.15)$$

[3] For a more rigorous presentation of the recursivity of the model see the Appendix.

where the term $\partial X_a/\partial P_a$ is the standard substitution effect of neoclassical demand theory. The change in the quantity consumed of a good given a change in its own price is negative, if the commodity in question is not an inferior good. Thus, the first term on the right hand side of equation 3.15 is unambiguously negative for a normal good.

The second term on the right hand side of equation 3.15, $(\partial X_a/\partial Y^*)(dY^*/dP_a)$, represents the profit effect. A change in the price of the agricultural good changes profits, and hence full income, through equation 3.10. This change in full income will, in turn, change the quantity demanded of the agricultural good, via the demand equation (eq. 3.14).

It remains to determine the sign of this profit effect in order to derive the full impact of a change in the price of an output which is consumed by the household. First, note that maximized full income (Y^*) given by equation 3.10 is a function of price levels (P_a, w) whose total differential is given by:

$$dY^* = (\partial Y^*/\partial P_a)(dP_a) + (\partial Y^*/\partial w)(dw) \qquad (3.16)$$

or, when w is unchanged:

$$dY^*/dP_a = \partial Y^*/\partial P_a. \qquad (3.17)$$

Substituting from equation 3.17, the profit effect term of equation 3.15 may be rewritten as:

$$(\partial X_a/\partial Y^*)(\partial Y^*/\partial P_a) = (\partial Y^*/\partial P_a)dP_a. \qquad (3.18)$$

Second, from equation 3.10, $\partial\pi^{*}/\partial P_{a} = X_{a}$ and $\partial Y^{*}/\partial P_{a} = X_{a}$, therefore

$$\partial Y^{*}/\partial P_{a} = \partial\pi/\partial P_{a}. \tag{3.19}$$

But Hotelling's Lemma states that $\partial\pi/\partial P_{a} = Q$ which allows us to rewrite the profit effect term as:

$$(\partial Y^{*}/\partial P_{a})dP_{a} = (\partial\pi/\partial P_{a})dP_{a} = (Q)dP_{a} \tag{3.20}$$

a term whose sign can be determined. The profit effect is therefore the product of the quantity produced and the change in price. Because quantities, Q, are always positive the sign of the profit effect is determined by the sign of the price change under study. The result is analogous to the well known result that the effect of an income increase is positive for a normal good.

A direct example will help make the impact of this result clear. The total change in the quantity of the agricultural good consumed by the household with a change in the price of that good is given by:

$$dX_{a}/dP_{a} = \partial X_{a}/\partial P_{a} + (X_{a})dP_{a}. \tag{3.21}$$

As stated earlier, the first term on the right hand side is the familiar substitution effect which is negative for a normal good. The second term on the right hand side has been defined as the profit effect. With an increase in output price the profit effect is unambiguously positive while the substitution effect is negative. Thus, the substitution and profit effects work in different directions with the same price change.

Therefore, the total effect of an increase in the price of an agricultural good produced and consumed by the household can have three possible outcomes. An increase in the price of the agricultural good may cause a decrease in consumption via a dominant substitution effect; an increase in consumption due to a dominant profit effect; or, the two effects could balance each other resulting in no measurable effect on household consumption due to an output price increase. The relative impacts of these two effects on the response of an agricultural household is indeterminate from theory. Thus, the particular response for any agriculturally based household economy must be determined through empirical means.

CHAPTER IV
PRODUCTION SIDE OF THE HOUSEHOLD

In this chapter the rationale for choosing a particular approach to estimating the production side of the household and a functional form are outlined. The Cobb-Douglas production function was chosen for estimation and is presented in the first section. Derivations of the input demand, profit function and profit-maximized output supply equations are also presented in the first section. The results of the ordinary least squares (OLS) estimation of the Cobb-Douglas production function are presented in section two. Production side elasticities are computed in section three, particularly the output price elasticity of profits needed for calculating the profit effect in Chapter VI.

The data used for estimating the production side of the agricultural household model came from a grain marketing study performed in Burkina that roughly coincided with calendar 1984. The data, while richly detailed on the consumption side, did not particularly focus on household production information. However, production relevant data were measured that would allow an uncomplicated characterization and estimation of the household production system. The data used in estimating the production side included

household field size by crop, harvest figures, labor force employed by the household (both family and non-family), expenditures on variable inputs and durable goods held by the household.

The area under cultivation in cereals by household, predominantly millet and sorghum, was aggregated to give a measure of land under cultivation. Labor was obtained from household demographic and composition changes plus use of market labor. Output was measured from the harvest figures and converted to kilograms of cereal using threshing rates determined for each household during the survey.

Cobb-Douglas Production Function

The alternatives considered for estimating the production side of the model were to use either a production or a profit (cost) function. A Cobb-Douglas production function was eventually chosen for three main reasons. First, the available data were more suited to a Cobb-Douglas production function than a profit (or cost) function approach. For example, a representative cost for land is extremely difficult to capture in the African agricultural setting. Second, actual factor use, and hence a production function, was preferred over factor input prices, and a profit (cost) function, because the former were available from the survey. Furthermore, factor input prices were not expected to vary significantly across households in a cross-sectional data

set. The third consideration was the ease of estimation, given that the consumption side of the model would take considerable time for data preparation, estimation and refinement a more straight forward production side estimation was preferred. Statistical testing of the appropriateness of the Cobb-Douglas approach in this case was also undertaken. In comparisons against other specifications, notably the translog and constant elasticity of substitution (CES), the Cobb-Douglas specification was not rejected.

A Cobb-Douglas production function consistent with the production constraint (Eq. 3.5) takes the specific form

$$Q = \alpha_0 A^{\alpha_1} L^{\alpha_2} \qquad (4.1)$$

where Q is total output, A is the area under cultivation (assumed fixed in the short-term) and L is the labor utilized in producing output. The expansion of this form to include variable inputs and capital is straight forward. The α_0 variable is a technological efficiency parameter that indicates the present state of technology. This can be seen from equation 4.1 by noting that for given values of the other production inputs (A and L), the value of α_0 will have a proportional effect on the size of output (Q).

For estimation purposes equation 4.1 is linearly transformed by taking natural logarithms to yield

$$\ln Q = \ln\alpha_0 + \alpha_1 \ln A + \alpha_2 \ln L \qquad (4.2)$$

Note that the output supply elasticities can be obtained directly from the parameter estimates of the linearly transformed Cobb-Douglas production function because

$$\epsilon_{QL} = (\partial Q/\partial L)L/Q = \partial \ln Q/\partial \ln L = \alpha_2. \qquad (4.3)$$

Factor demand equations are obtained from the first order conditions of profit maximization that equate the value of the marginal product of a factor to its wage cost, assuming perfectly competitive markets or

$$\partial \pi/\partial L = P_a(\partial Q/\partial L) = w. \qquad (4.4)$$

Thus, the household will employ labor, in this case both on-farm labor and off-farm labor, until the marginal product of the marginal worker equals the real wage rate.

Note that equation 4.4 has only one endogenous variable, L, and, thus, can be solved in terms of P_a, w, the parameters of the production function and the fixed area of land, A. The general solution to equation 4.4 can now be written as:

$$L^* = L^*(P_a, w, A). \qquad (4.5)$$

This result is important because none of the other endogenous or choice variables appear in equation 4.5, which emphasizes that household consumption decisions do not impinge on production decisions in this model. Thus, production decisions are made separate from consumption decisions; they are separable decisions.

Multiplying both sides of equation 4.4 by L/Q gives

$$P_a(\partial Q/\partial L)L/Q = wL/Q \qquad (4.6)$$

whith can be solved for the household demand for labor as

$$L = \alpha_2(P_a/W)Q. \tag{4.7}$$

where Pa is the output price of the agricultural commodity and w is the wage rate.

The restricted profit equation (profits minus variable costs) is then given by

$$\pi = P_aQ(A,L) - wL \tag{4.8}$$

which, with substitution from equation (4.7), simplifies to:

$$\pi = \alpha_1 P_a Q \tag{4.9}$$

when $\alpha_1 + \alpha_2 = 1$.

The profit-maximized output supply equation can then be obtained by substituting the input demand equation (eq. 4.7) in the original Cobb-Douglas production function (eq. 4.1) whith simplifies to:

$$Q = \left\{ a_0 X_1^{a_1} \left(a_2 \frac{P_a}{w} L \right)^{a_2} \right\}^{1/(1-a_2)} \tag{4.10}$$

In addition to the above Cobb-Douglas specification, a translog model was estimated that included squared terms for the two factor inputs and an interaction term between these inputs. Since the Cobb-Douglas model is a special case of the translog model, the former can be tested as a restricted case of the latter. When the appropriate F-test was performed the hypothesis that the Cobb-Douglas model was appropriate was not rejected at the 99% level of significance.

The Cobb-Douglas specification was also tested against the CES production function. Once estimated, the CES was tested for constant returns to scale (unable to reject at the 95% level of significance) and then reestimated with this restriction imposed. The resulting CES with constant returns to scale was tested against the Cobb-Douglas. Again the Cobb-Douglas specification was not rejected at the 99% level of significance (nor at the 95% level of significance, contrary to the test against the translog). With these results the Cobb-Douglas estimates were retained for the model estimation.

Other concerns entered into the choice of the Cobb-Douglas specification. The needs of the agricultural household model, functional form tractability and data availability constraints precluded the use of a translog approach in the present case. Recall, that the main production side result required for the agricultural household model is the responsiveness of profits to changes in output price. Unfortunately, "it is not possible to derive the first order conditions for profit maximization and substitute them into the translog production function to give a price-based translog production function (Haughton, 1986, p. 207)" as was done with the Cobb-Douglas specification.

An alternative approach would have been to derive the restricted profit function from a direct production function. Again tractability is a problem as "this works neatly

in the Cobb-Douglas case, it is not analytically possible for a translog production (sic) (Haughton, 1986, p. 209)." The direct specification of a profit, or cost, function would require information on input prices that is not available in the Burkina data. Profit and cost function approaches were unavailable because the input price data were not sufficient to support estimation. Furthermore, it is particularly difficult to value the two major inputs in the African agricultural household production system; family labor input and land to farm production.

Choice of specification can often have constraining impacts on model results that must be noted prior to estimation. The impact of using a Cobb-Douglas specification on the resulting production side elasticity estimate have been mentioned by other writers. Previous studies have shown that the estimates of direct (quantity-based) production functions generally result in larger elasticity estimates than indirect (price-based) production functions. "Once again the direct estimates show far greater responsiveness (Haughton, 1986, p. 215)."

Other *a priori* constraints on the results that are specific to a Cobb-Douglas specification include constant unitary elasticity of substitution, input elasticities of output that are invariant to output level, and strictly positive input quantities. In spite of these restrictions,

the Cobb-Douglas approach can give useful results as Haughton points out:

> However, the superiority of a homogenous translog form over the Cobb-Douglas form should not be overstated; both have fairly close fits . . . Depending on what issue is being addressed, the simpler Cobb-Douglas form may be adequate. Both give essentially similar output elasticities with respect to inputs (at the geometric mean values of the variables). (Haughton, 1986, p. 213)

Awareness of these and other impacts of model specification should be retained and used to temper the interpretation of the final results.

Additional explanatory variables, other than land and labor, were also created from the raw household data to represent expenditures on variable inputs (fertilizer, seed, insecticides, etc.) and capital inputs (durable good holdings as a proxy). Their inclusion in the model did not add additional explanatory value and hence were not retained for the final estimation. Moreover, few households in the sample reported using inputs other than land and labor.

Another likely omitted explanatory variable is farm management. Surrogate variables based on the age and educational level of the head of household were added to the basic model to capture the variance of management capability across households. The resulting specifications did not add explanatory power to the model with management proxies based on age, head of household educational level and maximum educational obtained within the household. These results can be explained by the lack of significant variance in levels

of education across households in the sample. Thus, the final estimating equation for the production side of the household model was the Cobb-Douglas specification using land and labor as explanatory variables for output.

Estimation Results

This section presents the results from the ordinary least squares (OLS) estimation of a Cobb-Douglas production function fitted to Burkina household data on output, area under cultivation and labor. Both the endogenous and exogenous variables were measured in volume rather than value form. Three dummy variables were added to the basic model to account for any differences in the production function across villages. Of course, the model with all dummy variables coefficients equal to zero holds for the fourth village in the sample (in this case Village 1).

Land and labor are normally considered endogenous (decision) variables with rental and wage rates exogenously determined. With land and labor decisions endogenously determined a simultaneity problem would arise in estimating a Cobb-Douglas function with OLS. However, other work on the Cobb-Douglas specification (Zellner, Kmenta and Dreze, 1966) has shown that if output is stochastic and the household-firm is assumed to maximize expected profits, then the resulting error terms of the OLS estimation are independent of the included endogenous variables. The result is that OLS

estimation of a Cobb-Douglas land-labor specification yields consistent parameter estimates assuming expected profit maximization.

The econometric model of household production behavior was first estimated with no restrictions on the parameter estimates. The resulting estimates were then tested to determine if the sum of the parameters on land and labor was significantly different from unity (i.e., constant returns to scale). The statistical test of this linear constraint would not allow rejection of the null hypothesis that the sum of the parameter estimates was one at the 95% level of significance. A confidence interval on the sum of the parameter estimates was determined at the 95% level of significance. The resulting range was from 0.71 to 1.59. The model was re-estimated under the restriction that $\alpha_1 + \alpha_2 = 1$. Note that the presence of CRS is consistent with profit maximization because of the assumption of fixed land under cultivation.

Results from both the unrestricted and restricted models are presented in Table 4.1. Note that the t-statistic values are significant at the 95% level for land, labor and the Village 2 dummy variable in both the unrestricted and restricted equations.

The R-squared values for both the unrestricted and restricted equations are not particularly high indicating that the model explains roughly 40% of the variance in

output. This kind of result is not surprising, particularly for primary, cross-section data. Barnum and Squire's (1979-a,b) Cobb-Douglas estimation in a monocropping environment explained roughly 67% of the variation in output. Haughton (1986) reported R-squared values of around 50%.

TABLE 4.1

UNRESTRICTED AND RESTRICTED
COBB-DOUGLAS PRODUCTION FUNCTION ESTIMATES

	UNRESTRICTED		RESTRICTED	
	PARAMETER ESTIMATE	t-STAT	PARAMETER ESTIMATE	t-STAT
Intercept	0.597	0.45	1.072	0.94
ln (Land)	0.414	3.38	0.394	3.32
ln (Labor)	0.739	3.26	0.606	-
Village 2	-1.778	-5.48	-1.747	-5.45
Village 3	-0.350	-1.02	-0.344	-1.01
Village 4	-0.107	-0.33	-0.131	-0.41
R^2	0.419	-	0.417	-

The definition of inputs and output variables could account for some of the unexplained variation remaining in the production estimation. For example, the output variable is an aggregate measure over both millet and sorghum. The assumption of a single production function for cereals may be a source of additional variability in the output variable. Although the major cereals, millet and sorghum, are generally aggregated together, a multicrop production

function could possibly add explanatory power. Further error could originate in the measures used for the explanatory variables, particularly labor. Labor quality can vary significantly across household, market and work party labor sources (Saul, 1983).

Omitted variables could also help explain the reduced R-squared value. The most likely exogenous variable that would add information to explain variable output would be one that captured the highly variable climatology of the Sahel. Unfortunately, this type of information, or a suitable surrogate, is not available at the household level. The village dummy variables add significant explanatory value to the model and can be interpreted as capturing some of the agroclimatological variation across the villages.

Another possible missing variable that could help interpret the lack of explanatory power is the quality of land. The variability of the quality of land is significant across households and could improve explanatory power in a revised estimate. Unfortunately, this variable, or a proxy, were not available for inclusion in this estimation.

Using the restricted estimation results from Table 4.1 the production side equations needed to proceed with the agricultural household model can be determined. The production function (for Village 1) can now be written as

$$\ln Q = 1.07 + 0.39{*}\ln A + 0.61{*}\ln L, \qquad (4.11)$$

the household demand for labor is

$$L = 0.61*(P_a/w)Q, \tag{4.12}$$

the restricted profit function is

$$\pi^r = 0.39*P_aQ, \tag{4.13}$$

and the profit-maximized output equation becomes

$$Q^* = 7.2*A*(P_a/w)^{0.78}. \tag{4.14}$$

Production Elasticities

This section outlines the derivation and calculation of the production side elasticities relevant to the agricultural household model. Using the parameter estimates from the previous section, a table of input demand and output supply elasticities is constructed. These elasticities are interpreted for their significance to production decisions and will be used in Chapter VI to determine the direction and magnitude of the profit effect and its impact on household output price responsiveness.

The coefficients on land and labor can be interpreted as the output supply elasticities, as was demonstrated through equation 4.3. Similarly, the restricted equation estimates can be used to determine the relative shares accruing to land and labor. From Table 4.1 it can be determined that the share for land is 39% while that of labor is 61%. In the same fashion, the impact on output of a 10% increase in labor is slightly less than twice that of a similar increase in land.

Barnum and Squire's Malaysia data indicated the reverse of the Burkina figures with 62 and 29% shares for land and labor, respectively. The balance being the shares of other variable inputs (8 percent) and capital (1 percent). This can be taken to imply that agriculture in Burkina is constrained more by labor than land. Thus, greater returns could be expected from addressing labor constraints than land constraints, although both would have a significant positive impact on production.

Production side elasticities more directly relevant to the agricultural household model can be directly computed from the output supply (eq. 4.10), labor demand (eq. 4.7) and profit (eq. 4.9) equations.[1] The resulting elasticity values and the formulae from which these estimates were derived are presented in Table 4.2.

In general, the results from Table 4.2 are consistent with earlier studies including Barnum and Squire (1979a,b) and Haughton (1986), both using Malaysian data. From the first two diagonal elements of Table 4.2, the own-price elasticities of output and labor can be interpreted. Output produced is very (positively) responsive to changes in the price of that output (in this case cereal price). As previously mentioned above, these direct, or quantity based,

[1] Taking logarithms of both sides of these three equations simplifies the derivation of the elasticity formulae.

estimates are expected to imply greater responsiveness than those based upon indirect or price based estimates.

TABLE 4.2

PRODUCTION SIDE ELASTICITY ESTIMATES

VARIABLES	ELASTICITIES		
	OUTPUT (Q)	LABOR DEMAND (L)	PROFIT (π)
OUTPUT PRICE (P_a)	1.56	2.56	2.56
(elasticity equation)	(α_3/α_1)	($1/\alpha_1$)	($1/\alpha_1$)
WAGE RATE (w)	-1.56	-2.56	-1.56
(elasticity equation)	($-\alpha_2/\alpha_1$)	($-\alpha_2-\alpha_1/\alpha_1$)	($-\alpha_2/\alpha_1$)
TECHNOLOGY PARAMETER (α_0) (elasticity equation)	2.56 ($1/\alpha_1$)	2.56 ($1/\alpha_1$)	2.56 ($1/\alpha_1$)

The high responsiveness of demand for labor to changes in the wage rate is also clear from Table 4.2. The value of -2.56 compares to -2.57 found by Haughton using Malaysian data and a Cobb-Douglas production function. Similarly, Barnum and Squire, using data from a more well-to-do area of Malaysia and a Cobb-Douglas production function approach, found -1.47. Assuming increasing population growth the high price responsiveness of household demand for labor can be expected to limit unemployment in the agricultural sector.

In addition to increasing output, an increase in output price will also induce greater demand for labor and higher profits. Wage rate elasticities have the expected negative

responsiveness for the elasticities listed in Table 4.2. An increase in the wage rate can be expected to reduce the demand for labor, thereby reducing both output and profits. Note that the direct influence on labor demand is greater than the induced declines in both output and profits indicating that labor is not the sole factor input in the household production process. Finally, the significance of technological change is high and can be expected to increase demand for labor, output and profits.

What is needed from this production side in terms of the agricultural household model is the impact of changes in output price on profits, the output price elasticity of profit. Table 4.2 reports a value of 2.56 for this elasticity implying that profits are highly responsive to output price changes. Haughton found this elasticity using a direct approach to be 3.06 while the indirect approach gave 1.89. The value for Burkina in Table 4.2 (2.56) is approximately halfway between these two extremes.

CHAPTER V
CONSUMPTION SIDE OF THE HOUSEHOLD

This chapter presents the consumption side of the household model. The consumer choice between goods to consume and labor to supply, modeled by an almost ideal demand system (AIDS), is presented in the first section. Estimation results from the AIDS model and restrictions from the neoclassical theory of demand (homogeneity and symmetry) are examined in the second section of this chapter. In the final section, expenditure, own and cross-price elasticities are calculated.

The data used to estimate the consumption side of the agricultural household are also from the Burkina grain marketing study. Recall that the household level survey from this marketing study provided the data for estimating the production side of the household in the previous chapter. Expenditure data from the same households used in Chapter IV are used in this chapter to estimate the consumption side of the household. These expenditures were obtained from fortnightly recall interviews in each household. The expenditure data were complemented with questionnaires designed to acquire information on quantities given (wages, gifts, exchanges, etc.) and received (salaries, gifts, remittances,

etc.). The final size of the sample set of households used was limited to the 87 households which had complete annual data on both production and consumption.

Almost Ideal Demand System (AIDS)

There are several alternative approaches to solving and estimating a system of demand equations. These include the linear expenditure system (LES), the log-linear expenditure system (LLES) and the Rotterdam approaches. Each of these systems approaches has its advantages and disadvantages depending upon the needs of the analysis.

Demand systems that are derived from an additive utility function, such as the LES, necessitate strong seperability of preferences and, possibly, own price elasticities restricted to linear relations of expenditure elasticities. The LES is derived from the Stone-Geary additive utility function. The LLES, on the other hand, requires expenditure elasticities equal to unity, which would inappropriately restrict the present study.

Another possible specification for the consumption side that would provide an opportunity to test the consequences of the neoclassical theory of demand is the Rotterdam model. The Rotterdam model is consistent with utility maximization for a linearly logarithmic utility function and has a similar specification to the AIDS configuration. However, unlike the AIDS, the Rotterdam model is not derived from

explicit preferences and demand functions (Deaton and Muellbauer, 1980a, p. 317).

The crucial points for choosing a functional form for the agricultural household model is the need for unrestrained elasticities and compatibility with theory. Prior restrictions resulting from the choice of functional form could limit the impact of the profit effect on consumer demand via the full income constraint.

Because of the need for a functional form that does not restrict parameter estimate values and related elasticities the almost ideal demand system of Deaton and Muellbauer was chosen for this study (Deaton and Muellbauer, 1980a). The AIDS model provides great flexibility for estimation and testing as Deaton and Muellbauer point out:

> . . . the Almost Ideal Demand System (AIDS), gives an arbitrary first-order approximation to any demand system; it satisfies the axioms of choice exactly; it aggregates perfectly over consumers without invoking parallel linear Engel curves; it has a functional form which is consistent with known household budget data; it is simple to estimate, largely avoiding the need for non-linear estimation; and it can be used to test the restrictions of homogeneity and symmetry through linear restrictions on fixed parameters. (Deaton and Muellbauer, 1980a, p. 312)

Most importantly for the present study, the AIDS model provides for flexible price and income elasticities which are necessary in estimating a household model because price and expenditure responses are the major points of interest. One should not constrain the elasticities to any particular

value (like the LLES), or range of values, in order that the full responsiveness of household expenditures to price and income changes can be captured.

Derived from utility maximization via a cost function by way of Shepherd's Lemma, the AIDS model can be succinctly written as

$$w_i = \alpha_i + \beta_i \log\left\{\frac{m}{P}\right\} + \sum_j \gamma_{ij} \log p_j \qquad (5.1)$$

where the share of expenditures allocated to good i (budget shares; $w_i = p_i q_i/m$) are determined as a function of the price of good j (p_j) and total expenditure (m) on all the goods being examined. Note that changes in relative prices impact on budget allocations via the gamma terms and changes in real expenditure impact via the beta coefficients. The beta coefficients can be interpreted as measuring necessities ($\beta<0$) or luxuries ($\beta>0$) depending on their sign.

The only non-linear element in the AIDS model of equation 5.1 is the price index term (log P) that deflates the value of total expenditure. From the derivation of the AIDS model this price index is defined as

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2}\sum_j \sum_k \gamma_{kj} \log p_k \log p_j \qquad (5.2)$$

The non-linear AIDS price index (logP) of equation 5.2 is often estimated by the Stone price index (logP*) which is given as

$$\log P_w^* = \sum w_k \log p_k \qquad (5.3)$$

The Stone price is an expenditure share weighted linear price index which is approximately proportional to P^*, if prices are highly collinear.

AIDS models that utilize the linear approximate (LA) Stone price index of equation 5.3 are often designated as LA/AIDS models. Having employed the Stone price index, the present study is an LA/AIDS model. The distinction between estimation of the AIDS, with the non-linear price index, and the LA/AIDS, with the linear Stone approximation, will be important in determining the appropriate computing formulae for elasticities of demand in section three below.

Estimation Results

For estimation purposes the household level data were pooled by considering each household separately over four time periods within the twelve month data collection period. Ray used a similar pooling technique to create panel data in estimating an AIDS model on household budget data from India (Ray, 1982). The benefits and costs of panel data over cross sections is discussed in other sources (Ashenfelter, Deaton and Solon, 1986).

The four time periods correspond to the different seasons in the agricultural sector of Burkina where behavior can be expected to vary. The four periods, corresponding to

quarters, are referred to as the cold (December to February), hot (March to May), rainy (June to August) and harvest (September to November) seasons.

Roughly 140 individual commodities were found in the raw data from the 87 households. These commodities were aggregated to four goods, plus labor supplied. The four goods were cereals (containing all cereal products), tobacco and beverages (including beer, soda and kola), other foods (non-cereal food purchases), and other non-food purchases. Time spent in leisure activities (broadly defined as all non-farm activities) was determined by subtracting the amount of agricultural labor time supplied by the household from the total time available. Thus, leisure is determined as the residual of the difference between household labor supplied on-farm and total time available.

Neoclassical demand theory is based upon a set of preference axioms and a linear budget constraint. Several restrictions on systems of demand equations can be derived from these two basic units of theory. These restrictions are known as adding-up, homogeneity of degree zero in prices, symmetry and negativity of price effects. Adding-up requires that the sum of the expenditures across all goods equal total expenditure and originates from the linear budget constraint.

Homogeneity of degree zero in prices implies that equal proportionate changes in both prices and expenditure will

not change the resulting demand. This is also known as the absence of money illusion, implying that consumers make consumption decisions upon relative prices, not absolute price levels. Homogeneity is also derived from the linear budget constraint.

Symmetry implies that the price effects of quantity demanded across any two goods will be identical. Acceptance of symmetry insures that the underlying preference structure is consistent. Negativity refers to the negative relation between the demand for a good and its own price, which is often called the "law of demand." These last two results derive from the specific axioms of preference underlying neoclassical demand theory. Deaton and Muellbauer provide details on the linear budget constraint, axioms of preference, and the derived constraints of demand (Deaton and Muellbauer, 1980b).

Full Information Maximum Likelihood (FIML) was chosen as the preferred method of estimating the AIDS model because it is invariant with respect to choice of equation dropped in the demand system (Greene, 1990, p. 528). Recall that in systems of demand estimation all commodity demand functions can not be included in the estimating procedure because this produces a singular covariance matrix. A singular covariance matrix results in an undefined likelihood function. Therefore, one of the system's equations is dropped in order to insure non-singularity of the covariance matrix. The parame-

ters of the dropped equation are then obtained from the adding-up conditions.

Both the unrestricted and restricted estimates were used to test the restrictions of homogeneity and symmetry using the likelihood ratio test. Adding-up is assured by dropping one of the equations, in this case the labor supplied by the household. In the AIDS model the testable restrictions imply the following

$$\sum_{i=0}^{n} \alpha_i = 1 \qquad \sum_{i=1}^{n} \gamma_{ij} = 0 \qquad \sum_{i=1}^{n} \beta_i = 0 \tag{5.4}$$

$$\sum_{j} \gamma_{ij} = 0 \tag{5.5}$$

$$\gamma_{ij} = \gamma_{ji} \tag{5.6}$$

for adding-up (5.3), homogeneity (5.4) and symmetry (5.5), respectively.

The unrestricted and restricted FIML estimates for the intercept, expenditure and own-price parameters of the LA/AIDS are presented in Table 5.1. Both homogeneity and symmetry were imposed in obtaining the restricted parameter estimates reported in Table 5.1 The results are encouraging with twelve and eleven of the fifteen coefficients listed being significantly different from zero (t-statistics greater than two) for the unrestricted and restricted estimations, respectively. Most of the significant changes in t-statistic values occur with the intercept terms.

TABLE 5.1

UNRESTRICTED AND RESTRICTED ESTIMATES OF THE LA/AIDS MODEL

		UNRESTRICTED			RESTRICTED	
		ESTIMATE	t-STAT		ESTIMATE	t-STAT
INTERCEPT	α_1	-0.520	-5.61		-0.014	-0.23
	α_2	-0.165	-3.43		-0.039	-1.84
	α_3	0.009	0.11		0.141	4.31
	α_4	-0.091	-0.99		-0.032	-0.69
	α_5	1.767	11.86		0.945	9.94
EXPENDITURE	β_1	0.047	5.79		0.052	5.94
	β_2	0.022	6.97		0.023	8.71
	β_3	0.010	1.84		0.004	0.84
	β_4	0.030	3.16		0.021	2.73
	β_5	-0.111	-6.98		-0.100	-7.06
OWN-PRICE	γ_1	0.111	16.78		0.075	10.29
	γ_2	0.022	-2.50		0.019	6.71
	γ_3	0.036	20.58		0.036	16.43
	γ_4	0.029	7.08		0.030	8.21
	γ_5	-0.049	-2.93		0.067	5.57

Note that the expenditure parameter estimates are positive for four out of the five goods in both the unrestricted and restricted models. As mentioned earlier, the AIDS configuration allows for classification of goods as necessities and luxuries depending upon the sign of the beta coefficients. Inspection of Table 5.1 results in the conclusion that cereals, tobacco and beverages, other foods and other non-food are all luxuries in the rural economy of Burkina. This is not surprising given the low absolute levels of incomes in the Sahel.

The share of total expenditures allocated to the consumption of leisure increases with increasing income. Recall that the labor supply equation is related to leisure demand through the total time available ($X_l = T - L$). The share estimated in this system is wL/m, which decreases with increasing income, thereby increasing wX_l/m. The broadly determined leisure variable is the only luxury in this system. Interpretation of the price parameters in the AIDS model requires calculation of the relevant elasticity estimates which are presented in the next section.

The likelihood values for both the restricted and unrestricted models were differenced, multiplied by two and compared to the chi-squared statistic to perform the likelihood-ratio test for the validity of the restrictions. The restrictions were rejected at the 95% level of significance. Symmetry and homogeneity were imposed separately and also tested. Both were rejected at the 95% level of significance.

The rejection of the restrictions derived from neoclassical demand theory is not unusual in empirical studies. "The restrictions of homogeneity and symmetry . . . are consistently rejected by the data (Deaton and Muellbauer, 1980b, p. 80)." In tests of the restrictions Ray found "that homogeneity is only marginally rejected for the household AIDS" (Ray, 1982, p. 360). In contrast, the "symmetry restriction is decisively rejected for the rural sector but only marginally for the urban sector" (Ray, 1982, p. 360).

In general, Ray's results found that the rural data were more likely to reject the demand restrictions than the urban data. This result was also dependent on whether or not household size effects were included in the model. The important point for this study is the choice between the unrestricted or restricted estimates in determining the demand elasticities. The decision is between statistically rejected restrictions from theory versus the results obtained from the theoretical structure employed.

Both unrestricted and restricted parameter estimates were used in deriving the consumption elasticities with no exceptional difference in elasticity values, particularly the expenditure elasticities. Therefore, restricted estimates were retained for the elasticity computations of the next section. It is not uncommon to impose theoretical restrictions in AIDS models without reporting significance tests (Bezuneh, Deaton and Norton, 1988).

The cross-price parameter estimates provided in Table 5.2 were not as impressive as those presented in Table 5.1. A total of 25 cross price parameters were estimated, or estimated and derived in the case of restrictions. The number of statistically significant cross price parameter estimates, at the 95% level, numbered 8 and 12 in the unrestricted and restricted models, respectively.

TABLE 5.2

UNRESTRICTED AND RESTRICTED ESTIMATES OF THE LA/AIDS MODEL

	UNRESTRICTED		RESTRICTED	
	ESTIMATE	t-STAT	ESTIMATE	t-STAT
GOOD 1 to 2	-0.006	-1.16	-0.015	-7.19
3	-0.001	-0.25	-0.011	-3.49
4	-0.002	-0.58	-0.015	-3.99
5	0.027	1.99	-0.033	-3.70
GOOD 2 to 1	-0.008	-2.50	-0.015	-7.19
3	-0.002	-0.91	-0.003	-1.86
4	0.001	0.69	-0.0005	-0.34
5	0.016	2.32	-0.0008	-0.24
GOOD 3 to 1	-0.023	-4.48	-0.011	-3.49
2	-0.005	-1.43	-0.003	-1.86
4	-0.005	-2.15	-0.002	-1.05
5	0.005	0.39	-0.019	-5.29
GOOD 4 to 1	-0.044	-4.59	-0.015	-3.99
2	-0.003	-0.55	-0.0005	-0.34
3	0.004	0.88	-0.002	-1.05
5	0.002	0.22	-0.012	-2.79
GOOD 5 to 1	-0.036	-2.57	-0.033	-3.70
2	-0.007	-0.92	-0.0008	-0.24
3	-0.037	-6.53	-0.019	-5.29
4	-0.021	-3.99	-0.012	-2.79

This percentage of statistically significant parameter estimates (one-third to one-half) from an AIDS estimation compares favorably with other studies. Deaton and Muellbauer reported 22 out 64 parameter estimates from British data with t-statistics greater than two (Deaton and Muellbauer, 1980a). Using Kenyan data, Bazunah, Deaton and Norton found

85 out of 124 parameter estimates that were more than twice their standard errors, but this figure included both cross price and other parameters (Bezuneh, Deaton and Norton, 1988). Finally, Ray's Indian data resulted in 21 out of 32 cross price parameter estimates with greater than "unit t values (Ray, 1982, p. 357)." Inspection of Ray's results reveals that 10 out of the 32 cross price estimates had t-statistics greater than two.

The poorer performance of the parameter estiestes for cross-price behavior can be attributed to the difficulties arising from aggregation across commodities. The four tangible consumables in this study consisted of varying numbers of individual commodities. Two of the goods created from the disaggregated data were composed of around ten commodities, namely Cereals (Good 1, 11 commodities) and Tobacco and Beverages (Good 2, 9 commodities). Other foods (Good 3) and other non-food (Good 4) were composed of 71 and 51 commodities, respectively. The difficulty in determining cross-price behavior from this level of aggregation is not surprising. Similarly, it is not surprising that the most significant cross price parameters arose for the least diverse good grouping (i.e., Good 1, cereals).

Consumption Elasticities

Consumption elasticities from the AIDS model have received considerable attention in recent years. Various

authors have used different elasticity computing formulae. The issue has been how to determine the price, both compensated and uncompensated, and income (expenditure) elasticities of demand. The problem derives from the use of the Stone price index as an approximation of the price deflator used in the AIDS model. Thus, the problem is between the linear approximate AIDS (LA/AIDS) and the non-linear AIDS (AIDS) computing formulae for price and income demand elasticities.

From equation 5.3 it is clear that the Stone price index is a function of the budget shares indicating that the budget share variable is endogenously determined. These shares are generally assumed to be constant when taking derivatives to derive elasticity computing formulae for the LA/AIDS. The confusion arises in the use of non-linear AIDS computing formulae where the shares are endogenous in computing elasticities for the LA/AIDS. Green and Alston, using the same data set under LA/AIDS and AIDS, have found that the use of AIDS computing formulae in calculating LA/AIDS elasticities will result in significantly different elasticity estimates than those from the non-linear AIDS (Green and Alston, 1990). Green and Alston present the correct elasticity computing formula for use with the LA/AIDS model.

AIDS elasticity computing formulae, with variable expenditure shares, should not be used with estimations of

the LA/AIDS, where expenditure shares are assumed invariant to changes in income. Assuming that the expenditure shares are invariant to income level is equivalent to assuming homothetic preferences (β_i=0 for all i), in which case the elasticity computing formulas are the same for both the AIDS and the LA/AIDS. However, if preferences are not assumed to be homothetic then the choice of computing formula is important.

In a follow-up article Green and Alston presented the correct LA/AIDS computing formulas for the uncompensated, compensated and expenditure elasticities (Green and Alston, 1991). The demand elasticity computing formulas for the LA/AIDS result in a system of simultaneous equations solved by matrix algebra. This was the approach used in computing the uncompensated and income compensated elasticities presented.

The uncompensated and income compensated elasticities are presented in Tables 5.3 and 5.4, respectively. The elasticity directions and values are reasonable for both prices and incomes. All own price elasticities are negative, as would be expected from rational consumers. Rural Burkina households adhere to the law of demand just as any other household. Own price elasticities are somewhat inelastic which could be due to the overall low level of consumption in the rural Sahel.

TABLE 5.3

UNCOMPENSATED DEMAND ELASTICITIES FOR THE LA/AIDS

COMMODITY GROUP	ELASTICITY OF DEMAND WITH RESPECT TO					
	Income	Price of Commodity Group				
		1	2	3	4	5
1) Cereals	1.35	-0.72	-0.06	-0.07	-0.09	-0.40
2) Tobacco and Beverages	1.83	-0.49	-0.52	-0.11	-0.08	-0.63
3) Other Foods	1.06	-0.12	-0.03	-0.65	-0.02	-0.24
4) Non-Food	1.35	-0.23	-0.00	-0.04	-0.69	-0.39
5) Labor Supply	0.72	-0.02	-0.00	-0.03	0.001	-0.67

TABLE 5.4

COMPENSATED DEMAND ELASTICITIES FOR THE LA/AIDS

COMMODITY GROUP	ELASTICITY OF DEMAND WITH RESPECT TO					
	Income	Price of Commodity Group				
		1	2	3	4	5
1) Cereals	1.35	-0.42	-0.01	0.07	0.02	0.33
2) Tobacco and Beverages	1.83	-0.09	-0.44	0.08	0.08	0.36
3) Other Foods	1.06	0.12	0.02	-0.54	0.07	0.34
4) Non-Food	1.35	0.08	0.05	0.10	-0.57	0.34
5) Labor Supply	0.72	0.14	0.02	0.05	0.07	-0.28

The income (expenditure) responsiveness of three of the five goods categories are significantly elastic. The high degree of income responsiveness of tobacco and beverages is

striking and may indicate the increasing integration of rural demand with goods produced in other sectors and regions. The only locally produced commodity included in Good 2 is sorghum beer. The exception to the high degree of income responsiveness is the labor supply that while still positive allows for the intuitively appealing result of increased consumption of leisure with increasing income.

The compensated demand elasticities of Table 5.4 allow direct interpretation of goods as complements, substitutes or independent commodities. The value of most cross price elasticities are very small, the exception again being the labor supply elasticities. Most goods appear to be slight gross substitutes with the only possible gross complements being cereals with tobacco and beverages. In general, using large aggregate commodity groups the own price elasticities are more responsive than the cross price elasticities. The cross price elasticities tend to reflect the income effect over the substitution effect in aggregate data.

Results from other studies using AIDS models at the household level tend to reinforce the conclusion of reasonable estimates from this side of the model. Ray found differing responses between rural and urban consumers using a non-linear FIML estimation of the AIDS model from Indian budget data (Ray, 1982). Ray's food group was a necessity and the other non-food group was a luxury. Most price elasticities had the correct signs and the most prominent

exception (other non-food) was attributed to aggregation error. Ray's expenditure elasticity for the food group was 0.71 while the price elasticity was -0.68 from rural time series data. Pooled data estimates resulted in higher estimates for both elasticities.

All but one of the own-price elasticities for the goods modeled by Bezuneh, Deaton and Norton using Kenyan data had the expected (negative) sign for both participants and non-participants in a Food-For-Work (FFW) scheme (Bezuneh, Deaton and Norton, 1988). The exception was the millet and sorghum good which had a positive own-price elasticity. The authors attributed the sign change of the uncompensated own-price elasticity to the impact of the profit effect (elasticity estimates for AIDS without the profit effect were not reported). The increase in demand for the millet and sorghum good with an increase in its price was credited to the increased income for farm households from higher prices.

The positive uncompensated own-price elasticity (0.67) was found for FFW participants and not among non-participants whose elasticity estimate (-0.53) was similar to that determined for Burkina (-0.72). Compensated price elasticities for the more comparable (to Burkina) non-participant sample were even more striking. The Kenyan non-participant millet and sorghum own-price elasticity was -0.49 compared to a similar cereals elasticity for Burkina of -0.42. Non-food uncompensated and compensated elasticities were also

similar between non-participant Kenyans and the Burkina sample (-0.72 and -0.62 for Kenya with -0.69 and -0.57 for Burkina, respectively).

Expenditure elasticities between the Kenya and Burkina data also compare favorably. Again comparing the results from the non-participant Kenyan sample with the Burkina data the expenditure elasticities for cereals were 1.04 and 1.35, respectively. The participant Kenyan households had an cereals expenditure elasticity of 1.53.

A final comparison is possible between rural and urban consumer behavior in Burkina derived from an LA/AIDS estimation. Savadogo and Brandt report elasticities for urban Burkina from 1982-83 which could be used to compare with the present rural results (Savadogo and Brandt, 1987). These authors found high uncompensated own price elasticities of demand for domestic cereals that ranged from -1.80 to -2.85, depending upon wealth category; wealthier households being more responsive. The income elasticity for locally produced cereals ranged from 0.63 to 1.13 with a sample mean of 0.94. Again, wealthier households were more responsive than less well off households.

The most appropriate comparison between the urban and rural elasticities is between the lowest income urban and the average rural household. The rural price and expenditure elasticities found in the present study are significantly different from those found by Savadogo and Brandt. Recall

that the uncompensated own price elasticity for cereals was -0.72, while the expenditure elasticity was 1.35. The implication is that rural households are less responsive to price changes and more responsive to income changes than urban households.

However, the comparisons between these two studies requires a significant caveat. The urban data, while estimated under an LA/AIDS model, used the non-linear AIDS elasticity computing formulas for deriving parameter estimates and subsequent elasticities. The Green and Alston result reported above implied that the resulting elasticity estimates would be incorrect.

Fortunately, Savadogo and Brandt also ran their data under an LES and reported the results. Using LES the income elasticity of demand for domestic cereals for the lower 25th wealth percentile was 1.29. This value compares favorably with the 1.35 value found for rural Burkina. The very different price elasticities can be explained by the choice of elasticity estimating formula and the lack of sufficient price variation in the urban data (Savadogo and Brandt, 1987, p. 32). In both the urban and rural models cereal demand is responsive to price changes, but further differences can be expected to arise once the profit effect is brought to bear. Urban consumers are not expected to be as widely influenced by a profit effect because they are generally not producers of the good they themselves consume.

CHAPTER VI
PROFIT EFFECT, POLICY IMPLICATIONS AND FUTURE RESEARCH

This chapter combines the results from both the production and consumption sides of the agricultural household to determine the importance of the profit effect on consumption of cereals in rural Burkina. After presenting the results in section one, the implications for policy in Burkina will be explored in section two. Finally, this chapter and the dissertation will close with some suggestions for avenues of future research that have become evident while undertaking the present effort.

The econometric results from both the production and consumption sides, presented in the final sections of chapters IV and V, respectively, were encouraging. Although the production and consumption side estimates are interesting, the purpose of this study is to use these results to measure the impact of the profit effect on consumption of the major commodity; cereals. The conclusion that remains from the previous chapters is that extreme departures from rational behavior were not found in the behavior of rural Burkina households. The results obtained for Burkina were also similar to findings from other studies. This tends to reinforce the view that rural households behave in an

economically rational fashion once the structure and constraints of the rural setting in a particular country are understood.

This study has reflected some of these constraints by incorporating the changing composition of the household over time in calculating labor availability and consumption. The dynamic nature of African household composition (by age and gender) requires regular monitoring. In this case household changes were monitored monthly. It was equally important to correctly identify the structure of the decision making unit in the regions studied, as mentioned in the Introduction. Correct specification of the "households" in the sample provided the basic unit of analysis which did not necessarily correspond to nuclear groupings.

Given the diversity of agroclimatic and social systems in Africa it is important to use the same (identical) households on both the production and consumption sides in estimating an agricultural household model. Other studies have not always been able to do this (for example, Barnum and Squire). The encouraging results from the econometric estimations could possibly be attributed to this fact. However, this approach has limitations because it restricted the degrees of freedom in estimation. Only those households with complete production and consumption data for the entire year were retained for analysis.

Finally, this work has served to reiterate the importance of clearly distinguishing what are properties resulting from a particular functional form used to model phenomena and what are the properties resulting from the data. This awareness tempered the results from the production side of the model and influenced the choice of the flexible AIDS model for the consumption side. One should always be aware of which results reflect properties of the chosen specification versus those that arise from the empirical data. This would seem to be especially important in estimating a system such as an agricultural household model where theory does not determine the direction or magnitude of the behavior under investigation (in this case the profit effect).

Profit Effect

Within the theoretical construct of the agricultural household model a change in an exogenous variable, such as the output price of the agricultural commodity produced, will have standard price and income effects on consumption plus a reaction in production decisions. The change in production decisions is captured through its influence on profits and is referred to as the profit effect. Because agricultural household models attempt to capture both the consumption and production responses of the household to exogenous changes, these models are likely to yield more

realistic results than an examination of each side of the household economy individually.

Recall from Chapter III that the influence of production decisions on consumption behavior enter through the full income constraint as profits. The full income constraint (equation 3.10) can be rewritten as

$$Y = \pi(P_a, w, \bar{A}) + wT + E \tag{6.1}$$

where π is profits and E adds the impact of exogenous income to the model. Exogenous income includes rents, remittances, gifts and other sources of income other than agricultural profits. As will become clear in this section, the extent of income diversification, as captured by E, in response to highly variable agroclimatic conditions will have a significant impact on the profit effect.

The combination of the profit equation from the production side (equation 4.13), the demand equations from the consumption side (equation 3.14) and the full income constraint from above (equation 6.1) provides the complete agricultural household model. Total differentiation of this complete household system of equations yields total response equations to exogenous changes. Written in elasticity form these equations for a change in an exogenous variable X (P_a, P_m, w or α_0) are given by

$$\left(\frac{\partial Z}{\partial X} \cdot \frac{X}{Z}\right)_{\pi} = \left(\frac{\partial Z}{\partial X} \cdot \frac{X}{Z}\right) + \left(\frac{\partial Z}{\partial Y} \cdot \frac{Y}{Z}\right)\left(\frac{\partial Y}{\partial \pi} \cdot \frac{\pi}{Y}\right)\left(\frac{\partial \pi}{\partial X} \cdot \frac{X}{\pi}\right) \tag{6.2}$$

or more succinctly as

$$\eta^*_{ZX} = \left(\eta_{ZX}\right) + \left(\eta_{ZY}\right)\left(\eta_{Y\pi}\right)\left(\eta_{\pi X}\right) \tag{6.3}$$

where the left hand term is the total elasticity with the profit effect and Z is the good consumed (X_a, X_m, or X_l). The first term on the right hand side of equation 6.3 is the price elasticity of demand. The remaining three terms on the right hand side are the expenditure elasticity of demand, profit elasticity of expenditures and the exogenous variable (price) elasticity of profits. Note that the profit elasticity of expenditures simplifies to π/Y from equation 6.1.

Using the elasticities computed for the production (Table 4.2) and consumption (Table 5.3) sides of the model the total effect can be calculated. The principal interest of this study is the impact of a change in the agricultural output price on the consumption of cereals (Good 1) by the household. These elasticities and the profit to full income ratio (π/Y) were evaluated at sample means with and without the profit effect. The resulting agricultural output price elasticities for the five goods with and without the profit effect are presented in Table 6.1.

The overall impact of the profit effect is to decrease the responsiveness of the household to price signals. Note however, that contrary to the expectations from the majority of other countries presented in Table 1.1, the Burkina price elasticities of demand do not change from negative to posi-

tive. The exception is the labor/leisure choice where an increase in output price does elicit an increase in labor supplied, thereby decreasing leisure consumed.

TABLE 6.1

OUTPUT PRICE ELASTICITIES WITH AND WITHOUT THE PROFIT EFFECT

	OUTPUT PRICE ELASTICITY OF DEMAND FOR				
	GOOD 1	GOOD 2	GOOD 3	GOOD 4	GOOD 5
WITHOUT PROFIT EFFECT	-0.72	-0.49	-0.12	-0.23	-0.02
WITH PROFIT EFFECT	-0.57	-0.29	0.00	-0.08	0.06

Further inspection of Table 1.1 in the Introduction indicates that not all countries experienced a sign change in their price elasticities of demand after the profit effect was introduced. Data from Japan, Thailand and Sierra Leone indicate that price elasticities of demand remained negative after including the effects of profits. The profit effect did, however, mitigate the price responsiveness in these three countries as was found in the Burkina data.

Two major reasons are suggested for the Burkina results. First, the level of income diversity in this part of the Sahel serves to reduce the overall impact of the profit effect through the full income constraint. As households diversify income sources away from agricultural production

the denominator of the π/Y term becomes larger, thereby reducing the impact of the profit effect.

Several authors have found diversified income strategies in this part of sahelian Africa. Reardon, Matlon and Delgado using data from the same time period and country as this study reported that in northern Burkina less than 30% of total income comes from agriculture (Reardon, Matlon and Delgado, 1988). They argue that this is a rational response to the highly variable agroclimatic conditions in this part of the Sahel. Similar results were obtained from household level surveys in neighboring Mali (Staatz, D'Agostino, and Sundberg, 1990).

A second complementary explanation for the results involves the point in time that the survey data were collected. The 1984 agricultural season was not a good year. "Rainfall during the 1984 cropping season was about 40% below long-term trends . . . (Reardon, Matlon and Delgado, 1988, pg. 1066)." The number of net consumers after a bad agricultural season is much larger than net sellers. The result on the profit effect is to reduce the number of households with significant contributions from agricultural profits to total income, again serving to reduce the π/Y ratio.

The sample mean for the π/Y term was 0.04 implying that, on average, only 4 percent of total income came from agricultural profits. In fact, the average exogenous income

for the sample was 2.5 times greater than average profits. For the consumption elasticities in Table 6.1 to change signs, 20 to 25% of total income would have to come from agricultural production. This would not be an unusual value to find in most agricultural settings (Reardon, Matlon and Delgado, 1988 and Staatz, D'Agostino, and Sundberg, 1990), but in the regions under investigation and in the period investigated most households sampled did not obtain one quarter of their full income, which includes valuing total time available to the household, from agricultural profits.

The valuation of total time available to the household can also have a significant impact on the π/Y term in the profit effect equation. As stated earlier, the valuation of labor is a difficult task in most any setting and this is particularly true in the Sahel. To make direct comparison of the present results to the other sahelian studies mentioned above the valuation of household time must be removed. When agricultural profits and exogenous income are evaluated for the sample mean from the present data the total income is roughly 36,000 French West African Francs (FCFA). This compares favorably with the range reported by Reardon, Matlon and Delgado (31-39,000 FCFA). The resulting share of agricultural profits in total (non-labor evaluated) income is then found to be around 26%, again very much in line with the earlier results.

Finally, recall the discussion in Chapter IV on the choice of functional form that implied increased responsiveness using a direct production function specification, particularly the Cobb-Douglas approach. Thus, the output price elasticity of profit is expected to be higher than it would be under other specifications. From the profit effect equation (eq. 6.3) this would imply that the profit effect observed could be somewhat overstated in this instance which, if corrected, would further reduce the impact of the profit effect in the current setting.

Policy Implications

The impact of including the production induced profit effect in determining household consumption response is clear from the results of the previous section. The absolute value of all but one of the estimated output price elasticities of demand decreased in value. Thus, traditional approaches to demand estimation would have overstated the magnitude of household responsiveness to price changes. This is important to keep in mind when interpreting consumption elasticities from traditional demand approaches in economic systems characterized by household-firms. The impact of increasing prices on profits will serve to mitigate the overall negative impact on demand.

The emergence of household income diversification strategies in response to variable agricultural production

will continue to mitigate the negative impact of price changes on the demand for cereals in certain areas. Perhaps a policy cue can be taken from this pattern of household behavior in supporting the emerging diversified income generating possibilities as a means of promoting household level food security. The impact of large seasonal and annual price changes in cereals in the Sahel may be better addressed through income programs rather than direct price interventions. Similarly, increased market dependence would imply that market based interventions may have greater impact in rural Burkina than previously thought.

Greater diversification away from own-production will continue the process of greater market dependence which argues for increased market information and infrastructure in these areas than has traditionally been the case. Existing market information systems (MIS) and infrastructure in the Sahel have focused more on those areas that are surplus producers than on areas that are moving towards greater dependence on the market. This is partly due to past decisions to locate most MIS in former grain marketing parastatals whose previous mandates had been to exert monopoly purchasing and resale of cereals. The exception to this is in Chad whose grain parastatal was never able to establish the institutional clout of neighboring sahelian states due to the civil war.

Even taking into consideration the impact of the profit effect, the overall responsiveness of rural Burkina households is striking. Rural households can be expected to respond in an economically intuitive fashion as long as agricultural profits are less than one-fifth to one-quarter of total income. The percentage of households in a particular area that will draw greater than 25% of total income from agriculture will be spatially specific in Burkina due to the different agroclimatic zones. Thus, those households living in particularly productive (agriculturally) areas can be expected to exhibit a sign change on the demand for cereals from negative to positive. In contrast, those areas with diversified income strategies will continue to exhibit the intuitive decrease in consumption with price increases. It may then be possible to determine the sub-national impacts of a change in pricing policy.

The highly elastic expenditure elasticities on non-food and non-local produced (tobacco and beverages) goods demonstrate the significant rural demand for production of goods from other sectors in the national and regional economy. Rural households are clearly more integrated with the national and regional economy (the cola nuts of Good 2 come from Ghana and Côte d'Ivoire) than some have thought. Given the greater level of market responsiveness, increased market integration as a policy goal should be considered.

The only negative compensated cross-price elasticity of demand may propose a unique opportunity for obtaining additional food security relevant information for policy makers. It is evident from Table 5.4 that the price of the tobacco and beverages good moves in a complementary fashion with cereals. Thus, an increasing price for cereals coupled with a decreasing demand for tobacco and beverages could be used as an early warning indicator of food insecurity for particular regions. Those regions where the profit effect is expected to predominate would be expected to exhibit the same change in consumption patterns. The high expenditure elasticity of demand for tobacco and beverages combined with a larger proportion of total income form agricultural profits would be expected to increase consumption of tobacco and beverages. Monitoring of market demand for the commodities in the tobacco and beverages good (principally, beer, cigarettes, coffee, soda and cola) would provide additional information from which to decide if households are making significant changes in their consumption habits in response to a price change.

Most striking is the degree of price and income responsiveness in the rural sector implying that there are opportunities for substitution between broad groups of commodities. This result is important in development planning in that it serves to reemphasize the importance of the price variable even in "subsistence" economies. In fact, the

implied level of integration with the market that is revealed through the income and price elasticities from this sample would bring into question the usefulness of the term "subsistence" in accurately describing these households.

The distribution of net sellers and net purchasers of cereals in Burkina and the Sahel can be expected to very across the country and over the years. This spatial and temporal distribution of the net seller/purchaser ratio may help in identifying those areas where residents would be expected to gain from an increase in agricultural prices and where people may migrate to avail themselves of not only a more favorable agricultural production climate, but also increased demand for labor. This increased labor demand is the only sign change result in the sampled data introduced through the profit effect.

Future Research

Suggestions for further inquiry into the nature of rural household behavior in Burkina focus on three general themes. First, the need for improved data collection elements that include what data to collect and how it is collected. Second, improvements in modelling the data once collected. Finally, some suggestions on what could be done to refine the present model or further examine the underlying data.

As mentioned above, individual estimations of either production or consumption would have benefitted from additional degrees of freedom. For example, this would have provided the opportunity to examine subsets of households within the sample. A larger sample size is usually preferable, but cost limitations can restrict the number of households surveyed. However, it is important to emphasize that existing and regular data collection instruments exist in most countries and could be slightly modified to meet the needs of household modeling. The inclusion of both production and consumption data needs in collecting household survey data should be stressed in this instance. Often the existing surveys focus on either production or consumption without realizing that with minimal additions both sides of household level behavior could be captured.

This study would have gained additional explanatory power if particular data elements on both sides of the household model had been of stronger quality. From the results of the production side of the model it is clear that subsequent studies on household production and consumption behavior should be as concerned about collecting information on prices and quantities of inputs used in production as budget surveys are on prices and quantities consumed by the household. The absence of price and quantity data of agricultural inputs limited the specification of the production side of the model and resulted in the use of a less flexible

specification. Particular attention should be addressed to obtaining relevant and reflective information on the prices and quantities of different types of labor (household, market and work party) and land, as well as other inputs. Other production side information that would have broadened the analysis include soil qualities and agroclimatic variation across households.

On the consumption side it would have been preferable to stratify the sample households by some of the wealth surrogates in order to more fully explore the issue of rural stratification and possibly different behavior patterns of households by wealth status. Greater detail on time allocation across and within households would have made the valuation of total time more accurate. The magnitudes and degree of diversity of the various income sources other than agriculture should always be explicitly addressed in the sahelian context.

Turning to elements of modeling in this context, one of the first areas of productive inquiry would be in attempting to integrate a multicrop production function rather than the single crop specification that was used. The multiple crops common to rural households may also provide a source of income to the household. This may be particularly true for specific subgroups within the household, for example the women in the household. It may also be productive to distinguish between millet and sorghum production, but this would

most likely require detailed information on soil quality and agroclimatic conditions. Millet prefers sandy soils and is more tolerant to drought than sorghum. Short of collecting new data, an index could be constructed to determine appropriate weights for the aggregation of millet and sorghum rather than the equal weights approach utilized here.

The specification used for the consumption side was a linear approximate AIDS (LA/AIDS). The appropriateness of this linear approximation could be tested by estimating the non-linear AIDS and testing for statistical significance. This would require using a non-linear estimation technique which is not difficult given the present state of desktop computing power. Such a test would determine whether the Stone price index and approximation is sufficiently different from the true AIDS. Elasticities could be calculated and compared for the LA/AIDS and true AIDS.

Green and Alston have reported preliminary comparisons using the same data set that found no significant differences in the elasticity estimates between the LA/AIDS and the AIDS (Green and Alston, 1990). They emphasize that this result holds as long as the correct elasticity computing formulas are used for the respective models. In concluding, these authors point out that their results may be "an artifact of the particular data set we analyzed (Green and Alston, 1990, p. 444)" and call for Monte Carlo studies for testing whether LA/AIDS is close to true AIDS. The present

data could provide a second set to test for significantly different elasticity estimates.

Further interesting refinements on the present approach are possible. These include incorporating risk and wealth effects, disaggregating price elasticities of demand, and relaxing two major assumptions from the present model, perfectly competitive markets (both input and output) and profit maximization. Wealth effects as measured by on-farm stocks and durable goods, disaggregated price elasticities and modeling under relaxed assumptions could possibly be supported by the same data from which the present study was undertaken.

The incorporation of risk in economic models has been particularly useful in agricultural economics because of the inherent uncertainty in agriculture. These risks are very apparent in the developing country context. In Burkina, and throughout the Sahel, a highly variable rainfall climatology is a major determining characteristic of agricultural performance. As noted in the production chapter, the lack of reliable household level information to reflect this variable was used to explain the relatively low explanatory power of the estimated production function. Better understanding of the riskiness of agricultural production systems in the Sahel would help explain the variability in output. Unfortunately, the Burkina household data from which the present work derives does not have suitable household level

information to reflect the variable rainfall regimes across households.

Production risk is difficult and costly to obtain at the household level, but price risk could possibly be incorporated given the temporal and spatial variability of the price data. Production risk studies in sahelian agriculture would probably require a different scale of analysis, perhaps at the sub-national, national or regional levels. Recent authors have outlined the demands of incorporating risk into the household framework (Finkelshtain and Chalfant, 1991).

Wealth rankings in the Sahel are often a function of on-farm stocks and durable goods held by the household. On-farm cereal storage is common in the Sahel when cereals are available. Almost every household has multiple granaries for storing grain on-farm. The value of these on-farm stocks would increase as prices increase, resulting in increased wealth for those households that can store grain. The presence and/or absence of these goods in a particular household will affect that household's wealth status and hence consumption decisions in the recursive household model. Renkow has recently provided a framework for incorporating levels of on-farm stocks in an agricultural household model (Renkow, 1990). The results from his empirical estimation did not result in significant changes in the calculated elasticities, although this will not always be the case. His

framework for the treatment of stocks could be implemented in the present model given additional time and effort to work from the raw data and incorporate changes in the present model.

The spatial variability of price and quantity data can be used to determine price elasticities of demand and allow disaggregation of the consumption side of the present model from the same data set. This would provide insights into price effects across specific commodities within the rural Burkina consumption bundle. A rural consumer price index could be created for monitoring household level impacts of price changes on a regular basis. If found to be correlated with certain locations or household characteristics this information could be used for targeting interventions to reach those households most in need. Deaton has outlined an approach for determining disaggregated price elasticities of demand from spatially varying data (Deaton, 1989).

Two major assumptions underlying the model presented in this research are that households are profit maximizers and that markets are perfectly competitive. Perhaps in the present setting the latter is a more specious assumption than the former. In both cases, modifications to the present model could be undertaken to better reflect reality. Ellis presents a very useful introduction and comparison of a variety of household models with differing decision-making

rules that includes the basic agricultural household model employed in the present research (Ellis, 1990).

If the labor market assumption is relaxed the recursivity of the model is lost and the system becomes simultaneous. The Appendix to Chapter 2 in Singh, Squire and Strauss presents the model without a functioning labor market (Singh, Squire and Strauss, 1986). Low offers a model in which wage rates are allowed to differ given quality differences in labor (Low, 1986). This would be interesting to explore in the Burkina case, if reasonably good labor market data were available. For instance, Saul reports a preference ordering for households that ranks family labor above hired labor above work parties (Saul, 1983).

An often overlooked, but important component, of household-firms is the nature of intrahousehold decision making, particularly its impact on health and nutritional status. Folbre presents an extensive review of this literature, including neoclassical, Marxist, and feminist perspectives (Folbre, 1986). Ellis is another source for information on modeling the inner workings of the agricultural household (Ellis, 1988). Intrahousehold studies require extremely disaggregated and extensive consumption, production and distribution data from the household. This type of information was not available from the Burkina household surveys used to estimate the present agricultural household model except on the consumption side.

APPENDIX
RECURSIVITY IN THE AGRICULTURAL HOUSEHOLD MODEL

A major characteristic of the agricultural household model is the recursive nature of the decision making process. A natural extension of the first order conditions from the optimization problem of the agricultural household model leads to a clear understanding of the recursive nature of the neoclassical theory of the agricultural household. In this Appendix the analytics that lead to recursivity under the assumption of competitive markets are presented in detail.[1]

Begin with the optimization problem as:

$$\text{MAX } U = U(X_a, X_m, X_l) \qquad \text{(A-1)}$$

subject to

(i) $P_a X_a + P_m X_m + wX_l = wT + q_c Q_c + P_a Q_a - q_v V - wL + E$

(ii) $G(Q_a, Q_c, V, L, K) = 0,$

a classical optimization problem subject to equality constraints.[2] Household utility is assumed to be a function of the consumption of three commodities; an agricultural good,

[1]. This section owes substantially to the Chapter 2 Appendix by Strauss (Singh, Squire and Strauss, 1986).

[2] The nonlinearity and inequalities of the previous presentation have been excluded to aid in the presentation.

X_a, a market good, X_m, and leisure, X_l. For this discussion assume that the household crop production vector consists of two crops; a cash crop, Q_c, and a food crop, Q_a.

The first constraint, the full income constraint, equates expenditures and income. Expenditures consist of the value of agricultural goods, $P_a X_a$, the value of market goods, $P_m X_m$, and the value of leisure time consumed, wX_l. Income is composed of the value of the household's time, wT, the value of a cash crop, $q_c Q_c$, the value of a food crop, $P_a Q_a$, minus the values of variable inputs and labor, $q_v V$ and wL, respectively, plus exogenous income, E. Examples of exogenous income sources include remittances, rents and non-farm income.

The second constraint introduces the limitations on behavior due to the household production process. An implicit production function is employed to describe the relationship between variable nonlabor inputs, V, total labor input, L, fixed inputs, K, and output, Q.

The Lagrangian function can now be constructed as:

$$\begin{aligned} \Phi = {} & U(X_a, X_m, X_l) \\ & + \mu[wT + q_c Q_c + P_a Q_a - q_v V - wL + E] \\ & - \mu[P_a X_a + P_m X_m + wX_l] \\ & + \theta[G[Q_c, Q_a, V, L, K)] \end{aligned} \qquad \text{(A-2)}$$

from which the first order conditions may be derived. In this problem the household has seven choice variables $(X_a, X_m, X_l, Q_c, Q_a, V, L)$ and two Lagrangian multipliers (μ and θ) for a total of nine first order conditions. Three of the

first order conditions involve decision rules for the quantities of goods consumed (X_a, X_m, X_l), two involve decision rules for the quantities of goods produced (Q_c, Q_a), two involve the quantities of inputs employed in the production process (V,L), and the final two involve the Lagrangian multipliers.

The three consumption based first order conditions are given by:

$$(1)\ \partial\Phi/\partial X_a = \partial U/\partial X_a - \mu P_a = 0 \qquad (A\text{-}3)$$

$$(2)\ \partial\Phi/\partial X_m = \partial U/\partial X_m - \mu P_m = 0$$

$$(3)\ \partial\Phi/\partial X_l = \partial U/\partial X_l - \mu w = 0$$

and the corresponding consumption Lagrangian multiplier condition is:

$$(4)\ \partial\Phi/\partial\mu = wT + q_c Q_c + P_a Q_a - q_v V - wL + E - P_a X_a - P_m X_m - wX_l$$

$$= w(T - L - X_l) + P_a(Q_a - X_a) + q_c Q_c + E - q_v V - P_m X_m$$

$$= 0.$$

The first order conditions for the two output decisions are given as:

$$(5)\ \partial\Phi/\partial Q_c = \mu q_c + \theta(\partial G/\partial Q_c) = 0$$

or: $$(1/\mu)(\partial\Phi/\partial Q_c) = q_c + (\theta/\mu)(\partial G/\partial Q_c)$$

and $$(6)\ \partial\Phi/\partial Q_a = \mu P_a + \theta(\partial G/\partial Q_a) = 0$$

or: $$(1/\mu)(\partial\Phi/\partial Q_a) = P_a + (\theta/\mu)(\partial G/\partial Q_a)$$

The first order conditions for the two input decisions are given as:

$$(7)\ \partial\Phi/\partial V = -\mu q_v + \theta(\partial G/\partial V) = 0$$

or: $$(1/\mu)(\partial\Phi/\partial V) = -q_v + (\theta/\mu)(\partial G/\partial V)$$

$$(8)\ \partial\Phi/\partial L = -\mu w + \theta(\partial G/\partial L) = 0$$

or: $$(1/\mu)(\partial\Phi/\partial L) = -w + (\theta/\mu)(\partial G/\partial L).$$

Note that there is no analogous first order condition for the capital input variable (K) because it is assumed fixed to the decision maker, although it is not considered immutable. The final condition involves the production Lagrangian multiplier as:

$$(9)\ \partial\Phi/\partial\mu = G(Q_c, Q_a, V, L, K) = 0.$$

The first order conditions represented by the nine equations in A-3 can be totally differentiated to yield:[3]

$$(1)\ U_{la}(dX_a) + U_{lm}(dX_m) + U_{ll}(dX_l) - \mu(dw) - w(d\mu) = 0 \qquad \text{(A-4)}$$

$$(2)\ U_{ma}(dX_a) + U_{mm}(dX_m) + U_{ml}(dX_l) - \mu(dP_m) - P_m(d\mu) = 0$$

$$(3)\ U_{aa}(dX_a) + U_{am}(dX_m) + U_{al}(dX_l) - \mu(dP_a) - P_a(d\mu) = 0$$

$$(4)\ -P_a(dX_a) - P_m(dX_m) - w(dX_l) = w(dL) - (T-L-X_l)(dP_l) -$$
$$P_a(dQ_c) - (Q_c-X_a)(dP_a) - q_a(dQ_c) - Q_c(dq_a) - dE + q_v(dV) +$$
$$V(dq_v) + X_m(dP_m) = \psi$$

$$(5)\ \theta/\mu[G_{cc}(dQ_c) + G_{ca}(dQ_c) + G_{cL}(dL) + G_{cv}(dV) + G_c d(\theta/\mu)]$$
$$= -dq_a$$

$$(6)\ \theta/\mu[G_{ac}(dQ_c) + G_{aa}(dQ_c) + G_{aL}(dL) + G_{av}(dV) + G_a d(\theta/\mu)]$$
$$= -dP_a$$

$$(7)\ \theta/\mu[G_{Lc}(dQ_c) + G_{La}(dQ_a) + G_{LL}(dL) + G_{Lv}(dV) + G_L d(\theta/\mu)]$$
$$= dw$$

$$(8)\ \theta/\mu[G_{vc}(dQ_c) + G_{va}(dQ_c) + G_{vL}(dL) + G_{vv}(dV) + G_v d(\theta/\mu)]$$
$$= dq_v$$

---

[3] Where $U_{la} = \partial^2U/\partial X_l\partial X_a$, $U_{lm} = \partial^2U/\partial X_l\partial X_m$, $U_{ll} = \partial^2U/\partial X_l\partial X_l$, etc.

(9) $G_c(dQ_c) + G_s(dQ_s) + G_L(dL) + G_V(dV) = 0$

These nine equations can be rearranged to form a 9x9 matrix as:

$$\begin{bmatrix} U_{ll} & U_{lm} & U_{ls} & -w & 0 & 0 & 0 & 0 & 0 \\ U_{ml} & U_{mm} & U_{ms} & -p_m & 0 & 0 & 0 & 0 & 0 \\ U_{sl} & U_{sm} & U_{ss} & -p_s & 0 & 0 & 0 & 0 & 0 \\ -w & -p_m & -p_s & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{\theta}{\mu}G_{cc} & \frac{\theta}{\mu}G_{cm} & \frac{\theta}{\mu}G_{cL} & \frac{\theta}{\mu}G_{cv} & G_c \\ 0 & 0 & 0 & 0 & \frac{\theta}{\mu}G_{mc} & \frac{\theta}{\mu}G_{mm} & \frac{\theta}{\mu}G_{mL} & \frac{\theta}{\mu}G_{mv} & G_c \\ 0 & 0 & 0 & 0 & \frac{\theta}{\mu}G_{Lc} & \frac{\theta}{\mu}G_{Lm} & \frac{\theta}{\mu}G_{LL} & \frac{\theta}{\mu}G_{Lv} & G_c \\ 0 & 0 & 0 & 0 & \frac{\theta}{\mu}G_{vc} & \frac{\theta}{\mu}g_{vm} & \frac{\theta}{\mu}G_{vL} & \frac{\theta}{\mu}G_{vv} & G_c \\ 0 & 0 & 0 & 0 & G_c & g_s & G_L & G_c & 0 \end{bmatrix} \begin{bmatrix} dX_l \\ dX_m \\ dX_s \\ d\mu \\ dQ_c \\ dQ_c \\ dQ_c \\ dQ_c \\ d(\frac{\theta}{\mu}) \end{bmatrix} = \begin{bmatrix} \mu dw \\ \mu dp_m \\ \mu dP_s \\ \psi \\ -dq_c \\ -dp_s \\ dp_L \\ dq_v \\ 0 \end{bmatrix}$$

which is clearly block recursive.

Note that each submatrix block above is itself a bordered Hessian matrix. The upper left block contains the information for the utility maximization problem while the lower right matrix contains the necessary information to solve the profit maximization problem. Because full income is determined in the production block the consumption block is dependent upon the result of the production block for its own solution. The system is block recursive in that the consumption decisions are partially determined by the outcome of the production decisions. However, the consumption decisions have no impact on the production decisions.

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BIOGRAPHICAL SKETCH

Although born outside of Atlanta in 1956, Charles Alan May moved to Florida in time to experience Hurricane Donna. He obtained all of his primary and secondary school education in Orlando, graduating from Edgewater High School in 1973. In 1977, he graduated from Colorado College in Colorado Springs, Colorado, with a bachelor's in chemistry and a Russian minor. After working for a year as an environmental chemist, he served two years as a Peace Corps volunteer in Ghana, West Africa, as a secondary school and junior college teacher. Upon returning to the U.S., he enrolled in a master's program at the University of Michigan in the School of Natural Resources.

Through the University of Michigan's Center for Research on Economic Development and the University of Wisconsin's International Agricultural Programs, Charles joined a team of researchers examining cereals markets in Burkina Faso, West Africa. He completed his master's degree in resource policy, economics and management at the University of Michigan, in 1987.

After two years of field and stateside work (Burkina and Madison) Charles enrolled in the Food and Resource Economics Department (FRED) at the University of Florida

(UF) in 1985. While a Ph.D. student in FRED he began consulting work for Tulane University's Center for International Health and Development. In 1988, Charles took a leave of absence from UF as a fellow at the Institute of International Economics in Kiel, Germany. This year-long program, with participants from several countries, was an intensive program in international macroeconomics, trade, development and finance.

Upon returning to the U.S. in 1989, Charles was employed by Tulane University as the staff economist on the Famine Early Warning System (FEWS) Project outside of Washington, D.C. Charles is presently employed with this project and returned to UF to complete his Ph.D. dissertation in the fall of 1991.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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